

# **Economic and Energy Impacts of Adaptive Reuse Building Construction**

by  
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**Author's declaration**

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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## **Abstract**

Adaptive reuse of buildings is an alternative to a building's end-of-life where a building's functional life may be extended to serve another purpose. Many studies suggest that adaptive reuse is more sustainable compared to typical demolition and new construction in terms of environmental, social, and economic impacts. However, these claims are qualitative in nature and are limited to economics at the project scale. This thesis quantifies the energy and economic impacts of adaptive reuse building construction in the Region of Waterloo (RoW) in Ontario, Canada. Input-Output (IO) models were developed to study the impacts of adaptive reuse building construction. First, an IO model was developed for Ontario. Then, it was regionalized into a two-region interregional input output (IRIO) model to study the RoW. The building construction industries' intermediate inputs and final demands were altered in the Ontario IO model to reflect changes in the building construction industries due to changes in the supply and demand of adaptive reuse buildings. A basic scenario represents the situation where only the building's superstructure and substructure are reused. The basic scenario was then extended to reflect the reuse of internal non-structural components. The IO models examine impacts to gross domestic product (GDP), industry outputs, employment and energy use, and comparisons are drawn between Ontario and the RoW. It was found that adaptive reuse building construction may benefit Ontario's and the RoW's economy and reduce energy consumption under certain combinations of changes in intermediate inputs and final demands. The desired domain of adaptive reuse construction, where energy use decreases, while GDP and employment increases, is discerned for both the residential and non-residential building construction industries in Ontario.

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## TABLE OF CONTENT

List of Figures.....	vii
List of Tables.....	viii
1 Introduction.....	1
1.1 Problem Statement.....	2
1.2 Objectives of the Thesis.....	3
1.3 Scope.....	3
1.4 Organization of Thesis.....	4
2 Literature Review.....	5
2.1 Definitions of adaptive reuse, deconstruction, and material reuse.....	5
2.1.1 Adaptive reuse.....	5
2.1.2 Deconstruction and techniques.....	5
2.1.3 Material Reuse.....	6
2.1.4 Connection of adaptive reuse, deconstruction, and material reuse.....	7
2.2 Benefits and Barriers of adaptive reuse.....	8
2.3 Adaptive reuse decision making tools.....	10
2.4 Case studies on adaptive reuse of buildings.....	14
2.5 Economics of adaptive reuse of buildings.....	16
2.6 Construction industry and the economy.....	16
2.7 Regional economic models.....	17
2.8 Application of Input-Output models.....	18
2.9 Summary – regional economic impact of adaptive reuse.....	20
3 Development of Input-Output model and fundamental concepts.....	22
3.1 The ordinary Input-Output model.....	22
3.1.1 Transaction matrix.....	22
3.1.2 Final demand and value added.....	22
3.1.3 Total industry outputs.....	23
3.1.4 Technical coefficients and the Leontief inverse.....	23
3.1.5 Accounting summary of ordinary Input-Output model.....	24
3.2 Commodity-by-Industry approach to Input-Output modelling.....	25
3.2.1 Use matrix.....	25
3.3 Import scrubbing Ontario Use matrix.....	26
3.3.1 Make matrix.....	27
3.3.2 Total commodity/industrial output, value-added, and final demand.....	27
3.3.3 Commodity output proportions.....	28
3.3.4 Developing ordinary Input-Output model from commodity-by-industry approach.....	28
3.3.5 Accounting summary of commodity-by-industry approach.....	29
3.3.6 Ontario IO data.....	30
3.4 Closing the two-region IRIO model with respect to households.....	31
3.4.1 Household column.....	32
3.4.2 Household row.....	32
3.4.3 Reintroducing households into provincial transaction matrix.....	33
3.5 Regional Input-Output model.....	33
3.5.1 Single region model.....	34
3.5.2 Estimating regional input coefficients with location quotients.....	34
3.5.3 Estimating regional gross output.....	37
3.5.4 Interregional approach to regional Input-Output models.....	37
3.5.5 Estimating interregional trade matrices, and regional final demand and output vectors.....	39
3.5.6 Verification of two-region IRIO model.....	40
3.5.7 Validation of regional household consumption.....	40
3.6 Hypothetical extraction and linkages.....	41
3.6.1 Hypothetical Extraction.....	41

3.6.2	Backward linkages .....	41
3.6.3	Forward linkages .....	42
3.7	Use matrix and final demand change .....	43
3.8	Energy use by industry.....	45
3.9	Jobs by industry .....	45
3.10	Toy model.....	46
4	Results and discussion.....	47
4.1	Scenario analysis of adaptive reuse of building construction industries .....	47
4.1.1	Fixed demand for adaptively reused buildings – Basic scenario .....	48
4.1.2	Fixed Demand for adaptively reused buildings – 10%, 45%, 90% scenarios .....	50
4.1.3	Scenarios for demand increase for adaptive reuse buildings.....	53
4.2	Energy use and job intensities .....	53
4.3	Results for adaptive reuse scenarios – Ontario.....	55
4.3.1	Economic profile of Ontario .....	55
4.3.2	Adjusting market share percentage .....	63
4.3.3	Adjusting percentage of non-structural components reused and demand increase.....	64
4.4	Results for adaptive reuse scenarios – Region of Waterloo .....	78
4.4.1	Economic profile of Region of Waterloo .....	78
4.4.2	Adjusting market share percentage .....	84
4.4.3	Adjusting percent of non-structural components reused and demand increase.....	85
4.5	Summary of results.....	91
5	Conclusion .....	94
5.1	Contributions and Key Findings.....	95
5.2	Future Research .....	96
	References .....	98
	Appendix A – Commodity, industry, final demand, imports, exports, and value-added labels.....	103
	Appendix B – Regional economic data .....	132
	Appendix C – Concordance of Energy use and detailed IO industry classification.....	135
	Appendix D – Validation of household consumption .....	145
	Appendix E – Toy models and supporting calculations .....	146
	Appendix F – Changes to Use matrix to reflect adaptive reuse of buildings.....	157
	Appendix G – 3D plots .....	160
	Appendix H – Plots of changes to output at aggregated level for each scenario.....	166
	Appendix I – Top 10 industry output decreases and increases for all scenarios.....	182

## List of Figures

Figure 2.1 - Concept map of material reuse .....	7
Figure 2.2 – Building end of life concept.....	8
Figure 2.3 – Sheila (2013) AdaptSTAR model.....	11
Figure 2.4 – Bullen & Love (2011a) adaptive reuse decision making model .....	12
Figure 2.5 – Yeung et al. (2015) steel reuse decision making process model.....	13
Figure 2.6 – Yeung et al. (2015) generalized decision making process .....	13
Figure 2.7 – Bon Curve.....	17
Figure 3.1 – Accounting summary of ordinary Input-Output model .....	25
Figure 3.2 – Commodity-by-industry accounting summary .....	30
Figure 4.1 – Energy intensities by aggregated industries .....	54
Figure 4.2 – Job intensities by aggregated industries .....	55
Figure 4.3 – Total economic activity in dollars for Ontario .....	56
Figure 4.4 – Total economic activity measured in energy for Ontario .....	56
Figure 4.5 – Ontario residential building construction commodity recipe.....	62
Figure 4.6 – Ontario non-residential building construction commodity recipe .....	63
Figure 4.7 – Market share vs total output change for Ontario.....	64
Figure 4.8 – Example of 3D plot .....	65
Figure 4.9 – Domain of negative and positive changes in total output for Ontario resulting from adaptive reuse of non-residential building industry.....	66
Figure 4.10 – Domain of negative and positive changes in total output for Ontario resulting from adaptive reuse of residential building industry .....	66
Figure 4.11 – Domain of negative and positive changes in jobs in Ontario resulting from adaptive reuse of non-residential building industry.....	67
Figure 4.12 – Domain of negative and positive changes in jobs in Ontario resulting from adaptive reuse of residential building industry .....	67
Figure 4.13 –Domain of negative and positive changes in total energy use in Ontario resulting from adaptive reuse of non-residential building industry.....	68
Figure 4.14 –Domain of negative and positive changes in total energy use in Ontario resulting from adaptive reuse of residential building industry .....	68
Figure 4.15 – Desired domain for adaptive reuse of non-residential building industry in Ontario .....	69
Figure 4.16 – Desired domain for adaptive reuse of residential building industry in Ontario.....	69
Figure 4.17 – Change in aggregated output resulting from adaptive reuse of residential building industry, ‘Basic,’ ‘10%,’ and ‘f2.5_basic’ scenario for Ontario.....	72
Figure 4.18 – Change in aggregated output resulting from adaptive reuse of non-residential building industry, ‘Basic,’ ‘10%,’ and ‘f2.5_basic’ scenario for Ontario.....	74
Figure 4.19 – Total economic activity in dollars for Region of Waterloo .....	78
Figure 4.20 – Total economic activity in energy for Region of Waterloo .....	79
Figure 4.21 – Region of Waterloo residential building construction recipe.....	83
Figure 4.22 – Region of Waterloo non-residential building construction industry recipe.....	84
Figure 4.23 – Market share versus total output change for Region of Waterloo .....	85
Figure 4.24 – Example of 3D plot – Region of Waterloo.....	86
Figure 4.25 – Percent of total output that each industry occupies in Ontario and Region of Waterloo.....	87
Figure 4.26 – Example of domain plot – Region of Waterloo.....	87
Figure 4.27 – Desired domain for adaptive reuse of non-residential building industry in Region of Waterloo.....	88
Figure 4.28 – Desired domain for adaptive reuse of residential building industry in Region of Waterloo.....	88

## List of Tables

Table 2.1 – Summary of Deconstruction techniques.....	6
Table 2.2 – Barriers of implementing adaptive reuse.....	9
Table 2.3 – Case studies relating to adaptive reuse of buildings .....	15
Table 3.1 – Dimensions of matrices in 2014 make and use data .....	30
Table 3.2 – Dimensions of matrices used in IO model.....	31
Table 4.1 – Scenario names and description .....	48
Table 4.2 – Concrete and steel material cost estimation .....	49
Table 4.3 – Existing and new <i>uij</i> reflecting adaptive reuse.....	50
Table 4.4 – Commodities to adjust for adaptive reuse recipe change.....	52
Table 4.5 – Final demand changes for adaptive reuse of building industries .....	53
Table 4.6 – Summary of hypothetical extraction for building industries in Ontario .....	57
Table 4.7 – Ontario’s top 20 backward linkages for each building industry .....	58
Table 4.8 – Ontario backward and forward linkages of households .....	60
Table 4.9 – Example of tables for top 10 increases and decreases in industry output.....	76
Table 4.10 – Generalization of top 10 increases and decreases in industry output .....	77
Table 4.11 – Summary of hypothetical extraction for building industries – RoW and Ontario.....	79
Table 4.12 – Region of Waterloo’s top 20 backward linkages for each building industry .....	80
Table 4.13 – Region of Waterloo’s backward and forward linkages of households .....	82
Table 4.14 – Example of tables for top 10 increases and decreases in industry output.....	90
Table A1 – Commodity labels at summary and detailed level.....	103
Table A2 – Industry labels at summary and detailed level .....	116
Table A3 – Final demand (consumption expenditure) labels .....	123
Table A4 – Final demand (gross fixed capital formation) labels.....	126
Table A5 – Exports, value-added, and imports labels .....	131
Table B1 – Concordance of industries in regional economic data and summary level.....	132
Table B2 – Employment data by metropolitan area .....	133
Table B3 – Employment data for regions of interests.....	134
Table C1 – Energy intensities for detailed IO industry classification .....	135
Table F1 – RoW changes to residential building construction recipe.....	157
Table F2 – RoW changes to non-residential building construction reipe .....	158



# 1 Introduction

Much of the infrastructure in developed countries has been built and may reach its end-of-life within this century. Furthermore, there may be a point in time where humans are required to construct vertically rather than horizontally due to the finite availability of land on Earth. In other words, humans will be forced to reuse developed lands and redevelop existing infrastructure. Scarcity of land is not the only barrier to infrastructure development; availability of natural resources also acts as a barrier. Similar to land availability constraints, there may be a point in time where the lack of natural resources will inhibit the growth and expansion of infrastructure. Since the construction industry is responsible for building infrastructure, it is desirable for the industry to adapt its methodologies and technologies to achieve environmental sustainability. As noted by Miyatake (1996), “realizing sustainable construction is the key for our industry to prosper sustainably in the 21<sup>st</sup> century” (p. 1)

The construction industry’s impact on the natural environment cannot be ignored and thus has an important role in achieving environmental sustainability. Canada’s construction industry produces 27% of the total solid waste in municipal landfills, of which approximately 75% can be recycled or reused (Yeheyis, Hewage, Alam, Eskicioglu, & Sadiq, 2013). The consumption of natural resources by the construction industry in the United States further illustrates the impacts the industry has on the natural environment. Through their literature review, Chong et al. (2009) found that “40% of all raw stone, gravel, and sand, 25% of all raw timber, 40% of energy, and 16% of the water, produced annually in the United States” (p. 1) were consumed by the construction industry. The construction industry’s negative impacts on the environment extends beyond North America; it is well known and observed around the world (Spence & Mulligan, 1995).

Miyatake (1996) believes that the following six principles of sustainable construction proposed by Professor Charles J. Kibert of the University of Florida should be practiced in the civil engineering and construction industry:

1. Minimize resource consumption
2. Maximize resource reuse
3. Utilize renewable or recyclable resources
4. Protect the natural environment
5. Create a healthy environment
6. Pursue high quality-built environments

These sustainable construction principles can be achieved through a circular construction process (Miyatake, 1996). The concept of circular construction is applied and repeated in literature under many names, and/or phrases, such as closed-loop material cycle (CLMC) construction (Sassi, 2008), closed material loops (Saleh & Chini, n.d.), circular economy in construction (Adams, Osmani, Thorpe, & Thornback, 2017), and closed-

loop recycling of construction and demolition waste (Weil, Jeske, & Schebek, 2006). An example of a construction process applied world-wide that follows the concept of circular and sustainable construction is the adaptive reuse (AR) of buildings (Bullen, 2007; Conejos, 2012; Conejos, Langston & Smith, 2013; Kurul, 2007).

Adaptive reuse is one of many methods for the construction industry to achieve sustainability. AR of buildings is an end-of-life alternative that extends the life of functionally obsolete buildings through repurposing its basic structure, and satisfies principles of environmental sustainability via encouragement of material reuse (Bullen, 2007; Conejos, 2012; Conejos et al., 2013; Langston, 2012; Langston, Wong, Hui, & Shen, 2008; Wilson, 2010; Yung & Chan, 2012). To further elaborate on adaptive reuse, buildings that are potential candidates for AR can be viewed as a collection of 'raw materials' (Langston et al., 2008). To extract these 'raw materials' from buildings requires a certain degree of deconstruction (i.e., AR requires partial and/or selective deconstruction of a building rather than deconstruction of the entire building (Chini & Bruening, 1999). The materials extracted from buildings through the process of deconstruction can be reused or recycled, hence exercising the concept of circular construction, and thus achieving environmental sustainability.

Literature to date on the economics of adaptive reuse is focused on the individual project economics rather than the wider economic impacts. Studies on the economics of building adaptive reuse, as well as deconstruction and material reuse, consist only of cost analyses (e.g., financial feasibility and cost benefit analysis). The objective of these studies was to determine if AR of a given building was profitable compared to other building end-of-life alternatives. In general, these studies do not provide solid indication that the adaptive reuse of buildings is a desirable option because the cost is dependent on the location and the building. That is, the cost of each adaptive reuse building is unique and does not address the impacts that spread beyond the project and into other economic sectors.

## **1.1 Problem Statement**

To understand the economic implications of AR, studies on the economics of AR need to expand beyond the focus of project economics and into regional economic impacts. Despite the plethora of literature qualitatively stating the positive economic (as well as social and environmental) benefits of AR of buildings, there are few studies quantifying the economic benefits. Moreover, structural changes in the economy due to the construction industry should be investigated when there are changes in the characteristics of construction activities (Pietroforte, Gregori, & Falagario, 2009). Since adaptive reuse alters the process of end-of-life construction stage, regional economic impacts of implementing adaptive reuse requires further investigation.

Several methods exist in the academic field of regional science to model the regional economy. These methods are Input-Output (IO) analyses, computable general equilibrium (CGE) models, social accounting

matrices (SAM), econometric models, mathematical programming (MP) as well as gravity models (Cassey, Holland, & Razack, 2011; Isard et al, 1998; Okuyama, 2007; Partridge & Rickman, 2010; Rose, 1995; Rose & Liao, 2005). Although there are several methods that can be applied in regional economics, two of the mentioned methods are widely applied to regional economic impact analysis: IO and CGE analysis (Cassey, 2009; Cassey et al., 2011; Rickman, 2010; Rose, 1995).

The application of IO and CGE analysis is extensive and their uses can be seen in other areas of engineering and academia. Applications and extensions of IO and CGE analysis includes, but are not limited to, disaster impact analysis (Hallegatte, 2008; Rose, Benavides, Chang, Szczesniak, & Lim, 1997; Rose & Liao, 2005), infrastructure impact assessment (AECOM, 2012; Dimitriou, Mourmouris, & Sartzetaki, 2015), energy and ecological/environmental analysis (Miller & Blair, 2009) and economic impact analysis (Cassey, 2009; Cassey et al., 2011). On the contrary, application of IO and CGE analysis is limited as it pertains to the construction industry's impact on the economy. Moreover, there are few to no applications of these methods on adaptive reuse – an end-of-life technique that inherently alters the construction industry – and its influence on the economy. In the case of Canada, “there is a lack of studies about the economic impacts of adaptive reuse on the economy” (Stas, 2007, p. 39).

## 1.2 Objectives of the Thesis

The objective of the thesis is to determine the economy-wide energy and economic impacts of adaptive reuse building construction in the Province of Ontario in general, and the Region of Waterloo in particular. This objective involves the following major research tasks:

1. Literature Review,
2. Data collection,
3. IO Modelling, and
4. Scenario analysis

A literature review was conducted on adaptive reuse of buildings, deconstruction, material reuse and economics of the construction industry to identify a gap in knowledge. Data collection consists of obtaining economic data necessary for economic modelling. Data collected included Make and Use (IO), regional employment, regional population, energy use, and adaptive reuse changes. These data were retrieved from Statistics Canada, and literature review. The collected data were operationalized into a two-region interregional IO model. Sixteen scenarios were developed to assess the sensitivity of economic impacts to changes in percent non-structural components reused, and percent increase in final demand.

## 1.3 Scope

The regions that will be assessed in this thesis are the province of Ontario in Canada, and the Region of Waterloo within Ontario. This will be accomplished by using regional economic modelling for the *ex ante*

study of the economic impacts of AR. The year that is evaluated in this thesis is 2014 because it was the most up to date data available at the start of this research. Adaptive reuse applies to buildings, so residential and non-residential building construction industries are the industries of interest within the economic model. The adaptive reuse scenarios analyzed are split into four categories. The first category is defined as 'Basic' adaptive reuse, where only the superstructure and substructures are reused. Also, included in 'Basic' adaptive reuse are increases to labour, and decrease in transportation of construction material. The second category extends the 'Basic' adaptive reuse, by including the reuse of non-structural components of buildings. The third category extends the 'Basic' adaptive reuse by including final demand for adaptive reuse buildings. The last category extends the 'Basic' adaptive reuse and includes both reuse of non-structural components, and final demand for adaptive reuse buildings.

#### **1.4 Organization of Thesis**

The organization of the thesis is as follows. Chapter 1 provides a brief overview of the research, its motivation, and objectives. Chapter 2 is a literature review on AR, deconstruction, and the relationship between the construction industry and the economy. Chapter 3 describes the methodology used to assess economic impacts of AR. Chapter 4 presents and discusses the results. Lastly, Chapter 5 concludes the thesis.

## **2 Literature Review**

This literature review is comprised of two main sections. First, background on AR is presented. Second, literature on the construction industry from the perspective of economics is presented.

### **2.1 Definitions of adaptive reuse, deconstruction, and material reuse**

The concept of AR comes from architecture, but its implications trickles throughout various disciplines such as civil engineering, planning, policy, environmental studies, etc. Because of this, literature on AR and its relevant concepts (deconstruction, and material reuse) contains various definitions. Thus, this thesis uses the following definitions in the forthcoming sections.

#### **2.1.1 Adaptive reuse**

By breaking down the word adaptive reuse into its constituents, the term can be interpreted as: to use something again or more than once for a new purpose. However, most architecture projects, and a number of studies, refer to AR as leaving the basic structure of the building intact, while altering its function (Langston et al., 2008). This definition is not fully correct as it assumes that AR is applied to buildings. Adaptive reuse by its definition can be applied to many physical objects. For example, a paper cup can be adaptively reused as a pen holder after its use of holding its original contents. Thus, when referring to AR, it is prudent to indicate its application.

For this thesis, AR is applied to buildings and this is defined as an end-of-life alternative that extends the life of functional obsolete buildings through repurposing of its basic structure, and satisfies principles of environmental sustainability via encouragement of material reuse (Bullen, 2007; Conejos, 2012; Conejos et al., 2013; Langston, 2012; Langston et al., 2008; Wilson, 2010; Yung & Chan, 2012). Adaptive reuse leaves the basic structure of the building intact. Thus, a certain degree of deconstruction is required, and an understanding of deconstruction is necessary in understanding AR.

#### **2.1.2 Deconstruction and techniques**

Deconstruction within the construction industry is the process of systematically disassembling physical infrastructure(s) for reusing or recycling (including downcycling and upcycling) components and/or construction materials.

There are various levels of deconstruction. Chini and Bruening (1999) describe three general levels of deconstruction : complete structural disassembly, soft stripping, or an individual assembly project. Smith & Hung (2015) describe five specific methods of deconstruction: destructive, non-destructive, complete,

selective, sequential, and parallel disassembly. A summary of deconstruction techniques from Chini and Bruening (1999) and Smith and Hung (2015) is shown in Table 2.1.

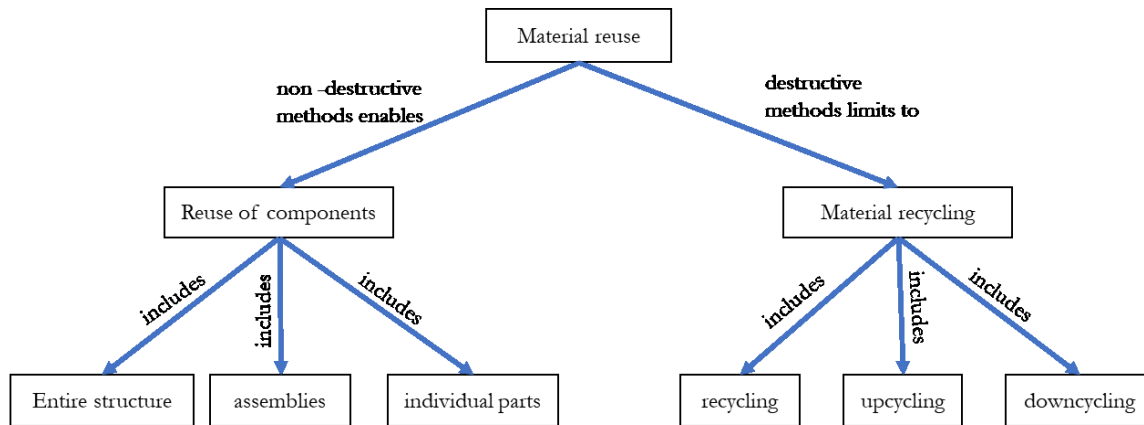
**Table 2.1 – Summary of Deconstruction techniques**

<b>Deconstruction techniques</b>	<b>Description</b>	<b>Source</b>
<b>Complete structural disassembly</b>	Buildings are qualified for complete structural disassembly when a large portion of materials can be reused	(Chini & Bruening, 2003)
<b>Soft-stripping</b>	Removal of specific components. For example, plumbing and electrical fixtures, appliances, HVAC, cabinets, doors, windows, flooring	(Chini & Bruening, 2003)
<b>Individual assemblies</b>	Removal of assemblies within the building. For example, rafters, floor joists, wall framing members, and sheathing materials	(Chini & Bruening, 2003)
<b>Destructive disassembly</b>	This method of disassembly prohibits future functional capabilities of the disassembled parts and only allows for recycling of material.	(Smith & Hung, 2015)
<b>Non-destructive disassembly</b>	Disassembly method that preserves the functional capabilities of the disassembled parts and allows reuse, repair, and remanufacturing of material.	(Smith & Hung, 2015)
<b>Complete disassembly</b>	A non-destructive method that disassembles all high value and low value parts	(Smith & Hung, 2015)
<b>Selective disassembly</b>	A non-destructive methods where only high value or high impact parts are disassembled	(Smith & Hung, 2015)
<b>Sequential disassembly</b>	A non-destructive method that removes one part at a time. This disassembly method prohibits disassembly of parts that are interlocked.	(Smith & Hung, 2015)
<b>Parallel Disassembly</b>	A non-destructive method that removes multiple parts in parallel. Unlike sequential disassembly, parallel disassembly can remove interlocked parts.	(Smith & Hung, 2015)

The purpose of deconstruction is to extract ‘raw material’ from physical infrastructures for reuse and recycling (Langston et al., 2008). Since literature on construction and demolition (C&D) reuse and recycling is plentiful, the next section elaborates on the definition of reuse and recycling used in this thesis.

### **2.1.3 Material Reuse**

Reuse and recycling are distinct in the construction and demolition (C&D) literature but become convoluted when applied in the context of AR and deconstruction of buildings. For this thesis, the term ‘material reuse’ is used and it comprises both component reuse and material recycling. Figure 2.1 is a concept map that illustrates the connection between these definitions.



**Figure 2.1 - Concept map of material reuse**

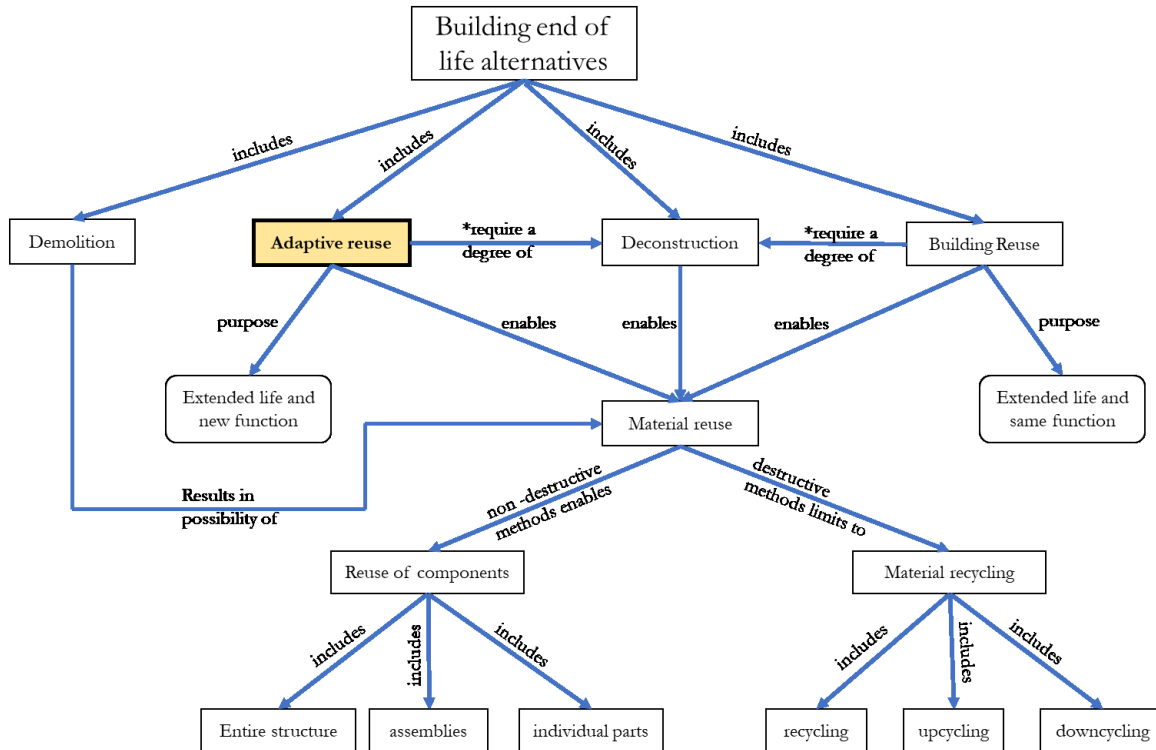
Deconstructing through non-destructive methods enables component reuse, which is reusing construction components (parts, products, assemblies etc.) for a similar purpose. An example of reusing construction components is taking a steel beam that was selectively disassembled from one building and using it again in another building. Components that are not candidates for reuse may be recycled for its raw material. Material recycling also composes of downcycling and upcycling. Recycling, downcycling, upcycling are explained below.

The process of reducing a raw material’s quality, potential for future uses, and economic value is called downcycling. The process of reusing a material for similar uses, thus maintaining the possibility for reuse again later, is recycling. The process of increasing the material’s quality, potential for future use, and economic value is called upcycling (Chini & Bruening, 2003).

Melting scrap steel and turning it into rebar or beams are examples of recycling. Crushing a concrete slab and using the crushed material as road base is an example of downcycling. Lastly, using lumber from deconstruction and creating tables, cabinets etc. and other added-value items is an example of upcycling (Kibert & Languell, 2000). Material reuse is an important factor in deconstruction and consequently is an important part of AR.

#### **2.1.4 Connection of adaptive reuse, deconstruction, and material reuse**

Understanding AR requires knowledge of deconstruction and material reuse, as well as how these three concepts are related to each other. Figure 2.2 is a concept map built on the proposed steel reuse decision making framework by Yeung, Walbridge, and Haas, (2015) to include AR of buildings and its conceptual relationship with deconstruction and material reuse.



**Figure 2.2 – Building end of life concept**

Adaptive reuse and building reuse are essentially the same except for one key factor: Adaptive reuse changes the purpose of the building while building reuse does not. Both AR and building reuse requires a certain degree of deconstruction, but the reverse is not true. That is, a deconstruction project is not necessarily an AR or building reuse project. Therefore, literature review on deconstruction and material reuse leads to a better understanding of AR of buildings.

## 2.2 Benefits and Barriers of adaptive reuse

The study of AR of buildings is relatively new, and the associated benefits are not fully understood. Numerous studies argue that AR of buildings brings about social, environmental, and economic benefits (Bullen & Love, 2011a; Chini & Bruening, 1999; Langston et al., 2008; Schultmann & Sunke, 2007; Smith & Hung, 2015; Wilson, 2010; Yung, Langston, & Chan, 2014). Social benefits associated with AR include maintaining heritage value, streetscapes, and sense of community; and salvaging of old building components to preserve architecture and craftsmanship. Environmental benefits include reduction of landfill waste, urban sprawl (Bullen, 2007), and extraction of raw material (Chini & Bruening, 2003). Economic benefits of AR mentioned in the literature include cost savings from pre-existing building structures and resale of deconstruction material; employment growth (Chini & Bruening, 2003; Langston et al., 2008); creation of material reuse market (Chini & Bruening, 2003); and increased property tax resulting from re-introducing a



function to previously vacant sites (Wilson, 2010). On the other hand, there are a lack of studies that quantify these benefits. Bullen and Love (2009) says “further research is needed to assess the viability of AR as a strategy for urban regeneration” (p. 9). Coelho and De Brito (2011) agrees stating that while “there seem to be clear [environmental] benefits” (p. 1), deconstruction still has “questionable economic appeal (in many cases)” (p. 1). Chapter 2.5 reviews literature on the economic analysis related to AR of buildings. Economic feasibility isn’t the only barrier to implementing AR of buildings: other barriers include building conditions and regulations. Most barriers of choosing AR as an end-of-life alternative can be categorized into three areas: finances, asset conditions (and technicalities), and political/regulations (Bullen & Love, 2011a). Table 2.2 summarizes the barriers to AR.

**Table 2.2 – Barriers of implementing adaptive reuse**

Category	Barriers	sources
<b>Finances</b>	<ul style="list-style-type: none"> <li>• building owners may see no economic benefit</li> <li>• overly complex transformations can be very costly</li> <li>• perceived financial risks may inhibit banks/re from financing projects</li> <li>• disposal costs of demolition are low</li> <li>• maintenance cost of adaptively reused buildings may be high</li> </ul>	(Bullen, 2007; Bullen & Love, 2011b; Shipley, Utz, & Parsons, 2006; Yung & Chan, 2012)
<b>Asset conditions (and technicalities)</b>	<ul style="list-style-type: none"> <li>• older buildings may not meet modern sustainability standards</li> <li>• older buildings may lack structural integrity</li> <li>• lack of equipment for deconstruction</li> <li>• not all buildings have appropriate components for reuse</li> <li>• construction industry is slow to accept reused material</li> <li>• lack of knowledge and skilled labour in the construction industry</li> <li>• deconstruction is slower than demolition</li> <li>• possibilities of site contamination</li> </ul>	(Bullen & Love, 2011b; Conejos et al., 2013; Shipley et al., 2006; Yung & Chan, 2012)
<b>Political/Regulations</b>	<ul style="list-style-type: none"> <li>• building code restrictions</li> <li>• lack of government support (incentives, funding, policies etc.)</li> <li>• poor perception of public’s view on reused building material</li> </ul>	(Bullen & Love, 2009; Bullen & Love, 2011b; Shipley et al., 2006)

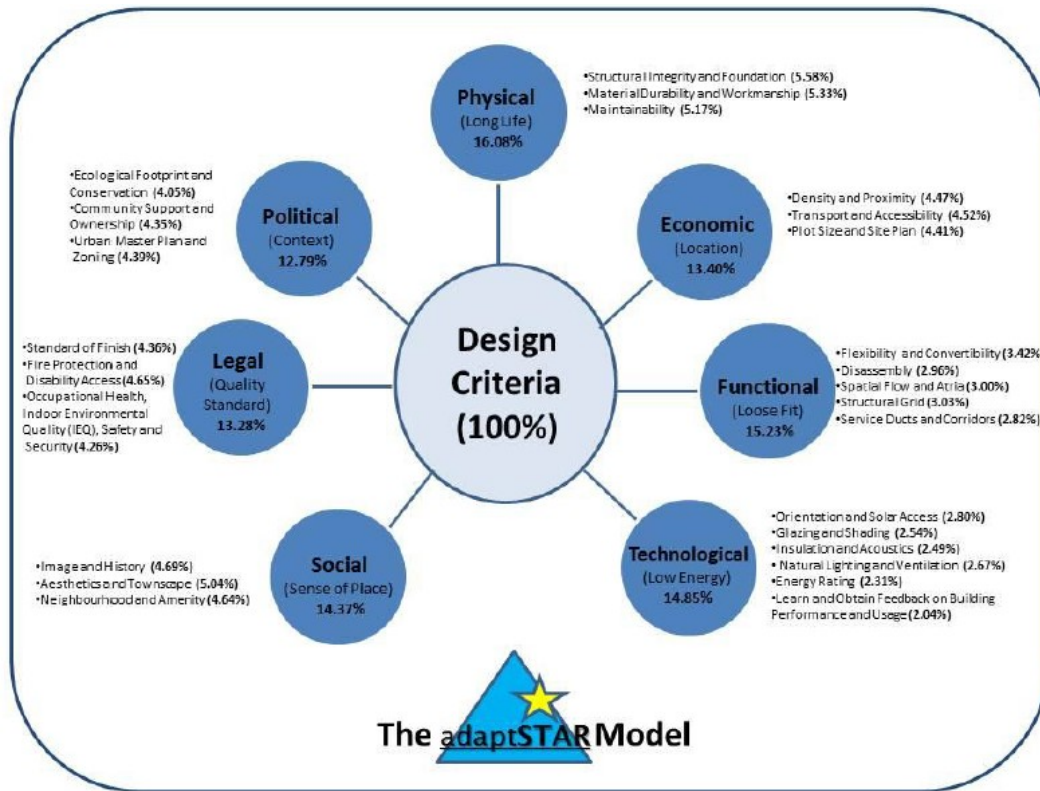
Despite the claims of economic, social, and environmental benefits that AR of buildings can bring, the decision to adaptively reuse a building is not a simple choice. There are financial, physical/technical, and political/regulatory barriers in the decision-making process of AR. Furthermore, there is a lack of research on the contribution to sustainability of implementing AR as an effective strategy in achieving modern sustainability goals (Bullen & Love, 2011b, 2011a; Coelho & De Brito, 2011). There are decision-making models to aid decision makers whether to select AR as a building’s end-of-life alternative.

### 2.3 Adaptive reuse decision making tools

There are three decision-making models specific to AR of buildings: Langston's (2008) *Adaptive Reuse Potential* (ARP) model, Conejos' (2013) *adaptSTAR* model, and Bullen and Love's (2011) decision model. Also, Chini and Bruening (1999) provides a qualitative guideline to assess a region's and projects' potential for deconstruction and Yeung et al. (2015) proposed a reuse decision framework to assess the potential of reusing structural steel components. Langston's model is quantitative while Conejos' and Bullen and Love's model are qualitative. Meanwhile, the steel reuse decision framework developed by Yeung et al. (2015) incorporates engineering analysis.

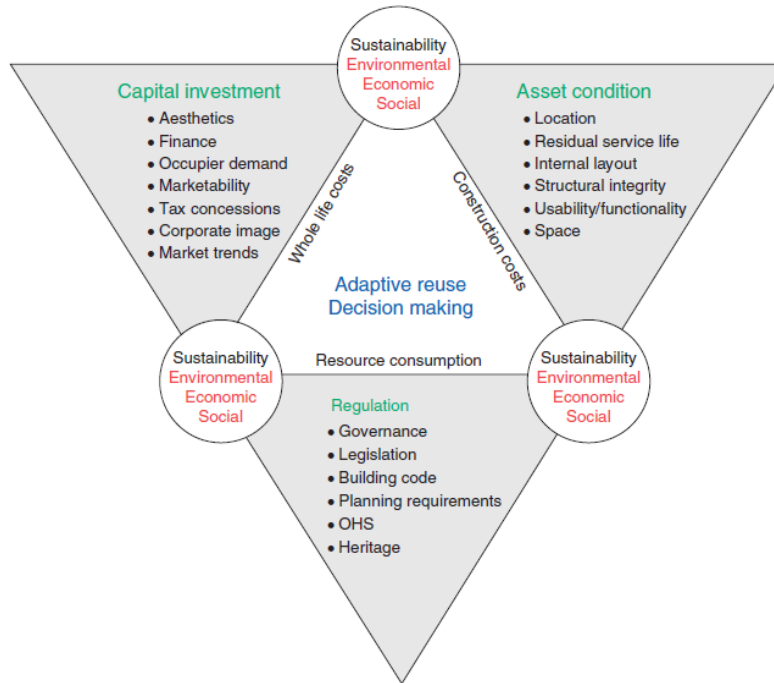
Langston's ARP model is applicable to all buildings in any country. Inputs of the ARP model are expected physical life, current building age, and six variables of obsolescence (physical, economic, functional, technological, social, and legal). The ARP model outputs a value that indicates the potential for a building to implement AR given its current age. The ARP model can be used to find the optimal time of implementing AR of existing building stocks (Langston et al., 2008).

Like Langston's ARP model, the *adaptSTAR* model is a rating tool to inform decision makers on the potential of a building to be adaptively reused. Conejos' *adaptSTAR* model was developed in three stages. Stage one of the *adaptSTAR* model development consists of identifying design criterion of implementing AR of buildings. This was completed through surveys of experts involved in AR building projects in Australia. Stage two determines the rank and weighting of each design criteria. Lastly, stage three is validation of the *adaptSTAR* model using Langston's ARP model. Figure 2.3 shows Conejos' design criteria and their corresponding weightings.



**Figure 2.3 – Conejos (2013) AdaptSTAR model**

Bullen and Love (2011a)'s decision model follows Conejos' model as it provides a list of decision criterion of implementing AR. Bullen and Love (2011a)'s analysis of 81 in-depth interviews with industry experts concluded that the decision criteria can be categorized into three categories; capital investment, asset condition, and regulation. Unlike Langston's and Conejos' models, Bullen and Love's decision model is not a rating tool that indicates an existing building's potential for AR. Rather it is a list of decision criterion for implementing AR. Figure 2.4 below is Bullen and Love's decision-making framework for AR of buildings.



**Figure 2.4 – Bullen & Love (2011a) adaptive reuse decision making model**

Chini and Bruening (1999) claims that feasibility of deconstruction needs to be assessed on two economic levels: regional economic and site economic. The feasibility of implementing deconstruction in a region is dependent on the region’s building stock, market for reused material, and public-sector involvement. A region’s capability of implementing deconstruction as a strategy requires ‘a large number’ of buildings that are suitable for deconstruction. A reused/salvaged material market must be present to meet the demand and supply. Lastly, government and local programs supporting deconstruction are needed to increase the opportunities for implementing deconstruction. On the other hand, the economic feasibility for deconstruction is decided by a cost benefit analysis against demolition.

Yeung et al. (2015) proposed a steel reuse decision model to aid decision makers determine the feasibility of reusing salvaged structural steel from a building at its end-of-life. This decision model is shown in Figure 2.5 and Figure 2.6. Figure 2.5 depicts steel reuse decision proposed by Yeung et al. (2015). Each decision step in Figure 2.5 requires a generalized decision process in which engineering analysis is involved.

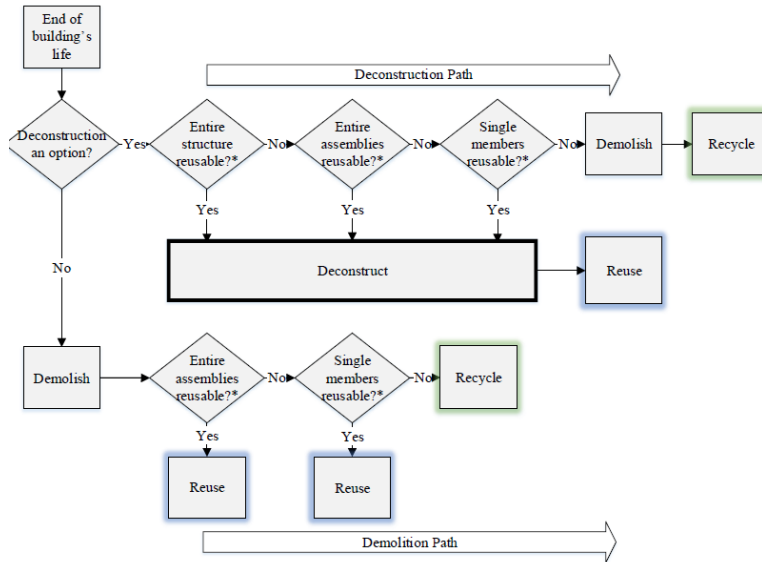


Figure 2.5 – Yeung et al. (2015) steel reuse decision making process model

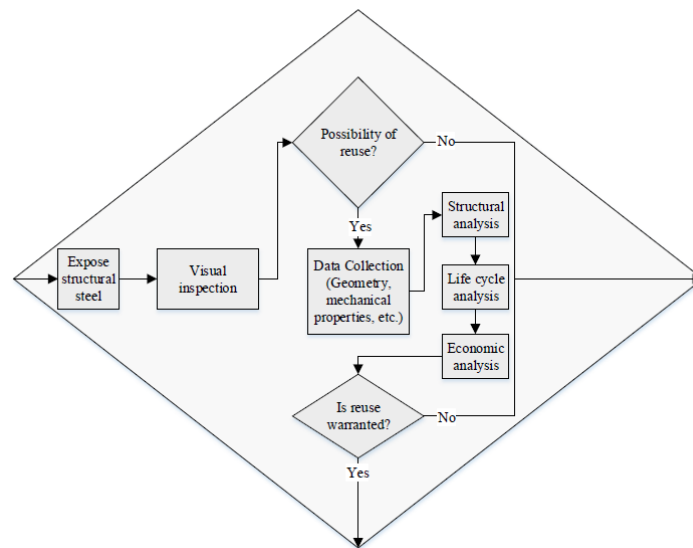


Figure 2.6 – Yeung et al. (2015) generalized decision making process

In summary, decision-making tools can aid decision makers in the decision process of selecting AR as a building's end-of-life alternative. However, these decision-making tools are focused on the project level economics, and do not reveal the effects that implementing AR building construction has on the regional economy. Furthermore, there is a lack of literature indicating the use of these decision-making tools. Many case studies on AR projects are *ex post* studies; only a few have been *ex ante* studies.

## **2.4 Case studies on adaptive reuse of buildings**

Adaptive reuse of buildings has been implemented around the world, yet the literature on this topic is not plentiful. The plethora of building AR projects enables countless case studies to be conducted. Table 2.3 summarizes case studies relating to AR of buildings found at the time of writing this literature review.

**Table 2.3 – Case studies relating to adaptive reuse of buildings**

Overview	Research methodology	Conclusions/findings/recommendations	Source
<b>Case study of 8 adaptive reused buildings in Toronto Ontario.</b>	<i>Ex post</i> study on 8 adaptive reuse buildings using in-depth interviews	<ul style="list-style-type: none"> <li>• Building site should not contain ground water contamination</li> <li>• Use concrete buildings if expanding existing structure</li> <li>• Select buildings that have interior gutted</li> <li>• Select buildings with incentives promoting adaptive reuse</li> </ul>	(Wilson, 2010)
<b>Community-initiated adaptive reuse of historic buildings in the Tianzifang district in Shanghai</b>	<i>Ex post</i> study conducted through site visits, interview with residents and tenants, and survey questionnaires	<ul style="list-style-type: none"> <li>• Community-initiated adaptive reuse achieves the aspects of sustainability as a whole</li> <li>• Public involvement in the adaptive reuse process is beneficial in achieving social, environmental, and economic goals in sustainable development</li> </ul>	(Yung, Chan, & Xu, 2014)
<b>Adaptive reuse potential of vacant industrial properties in Stoke-on-Trent</b>	<i>Ex post</i> study using 1997/1998 data	<ul style="list-style-type: none"> <li>• Retains character</li> <li>• Often cheaper than constructing a new building</li> <li>• Unfailingly more sustainable than new buildings</li> <li>• Generates economic development</li> </ul>	(Ball, 2002)
<b>Adaptive reuse of Hotel Penaga in Malaysia</b>	<i>Ex post</i> study through literature review, study available diagrams, site observation, and interview with Architect	<ul style="list-style-type: none"> <li>• Claims as an excellent example of privately funded adaptive reuse project</li> <li>• Achieved Green Building Index Gold rating</li> </ul>	(Dewiyana, Ibrahim, & Hajar, 2016)
<b>Financial feasibility of adaptive reuse in comparison to two hypothetical construction development options</b>	<i>Ex ante</i> case study using cost benefit analysis and pro-forma analysis	<ul style="list-style-type: none"> <li>• no formula to determine profitability of adaptive reuse</li> <li>• Cost benefit and pro-forma analysis may have contradicting results</li> <li>• Major factors affecting financial feasibility of adaptive reuse are construction costs, total area of building, and value of property</li> </ul>	(Stas, 2007)
<b>Lessons learned on adaptive reuse in Los Angeles, United States.</b>	<i>Ex post</i> study using the ‘lessons learned’ approach	<ul style="list-style-type: none"> <li>• Attraction to implement adaptive reuse relies on leniency in codes and zoning requirements, as well as providing financial incentives</li> <li>• Sustainability benefits of adaptive reuse outperforms that of demolition</li> </ul>	(Bullen & Love, 2009)
<b>Lessons learned from two Canadian projects that utilized material reuse.</b>	<i>Ex post</i> study using the ‘lessons learned’ approach	<ul style="list-style-type: none"> <li>• Reusing building site/components may eliminate some unknowns</li> <li>• Knowing the characteristics (drawings/ specifications) increases reuse opportunities</li> <li>• It is easier to reuse structural components for similar purposes</li> <li>• Hot-rolled structural steel with bolted connections and large timber members have greater opportunities of reuse than their lightweight counterparts</li> <li>• Joints with screws and bolts are easier to deconstruct than fixed joints (e.g. welds)</li> <li>• Willingness of client to commit to deconstruction and material reuse, as well as education of industry on the topic is crucial</li> <li>• Implementing deconstruction and material reuse strategies are project specific and time dependent</li> </ul>	(Gorgolewski, 2008)
<b>Adaptive reuse in sustainable development</b>	<i>Ex-post</i> study using surveys	<ul style="list-style-type: none"> <li>• Developed weighting and ranking based on economic, social, and environmental factors.</li> <li>• Weighting and ranking system applied to six case studies in Toronto, Ontario</li> <li>• Claims that the weighting and ranking system can accurately assess sustainability levels of adaptive reuse projects</li> </ul>	(Tam & Hao, 2018)

Most case studies are *ex post* studies that do not illustrate the economic impacts of implementing building AR as a strategy in achievable sustainability goals. *Ex ante* studies are needed to understand potential impacts, but again, *ex ante* studies related to AR of buildings aren't common and are limited to costs analyses. The following section provides an overview of the economics of AR of buildings.

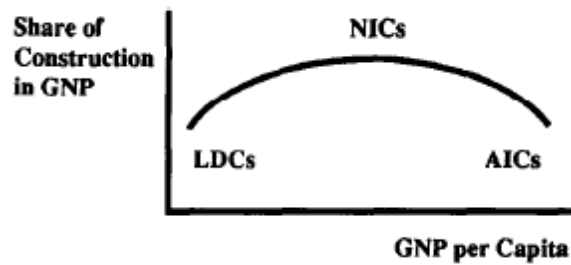
## **2.5 Economics of adaptive reuse of buildings**

The Literature review reveals that there is a lack of studies on the economic impacts of AR of buildings on the economy. Stas (2007) confirmed this to be true for Canada in his literature review. At the time of writing this literature review, there are no studies that have investigated the economic impacts of adaptively reusing buildings. Nonetheless, there are several methods (cost benefit analysis, prediction models, system dynamics) used for determining the costs of AR of buildings. Stas (2007) did a cost benefit analysis (CBA) on AR of buildings and compared it to greenfield and brownfield development. Tatiya, Zhao, Syal, Berghorn, and LaMore (2017) developed a cost prediction model for deconstruction. Coelho and De Brito (2011) conducted a cost comparison of demolition and deconstruction. Begum, Siwar, Pereira, and Jaafar (2006) did a CBA on construction waste recycling and reuse. In their review paper Yuan and Shen (2011) found that between the years of 2000 and 2009, only three economic studies were conducted on construction and demolition waste management (these studies used CBA). Lastly, Marzouk and Azab (2014) determined the cost of recycling versus disposing using systems dynamics. In short, there are numerous studies that look at the costs relating to AR of building, but there is still a lack of research on the economic impacts resulting from changes in the construction industry from implementing AR as a building end-of-life alternative.

## **2.6 Construction industry and the economy**

The construction industry is an important industry in a country's economy. There are numerous studies investigating the relationship between the construction industry and economic development. In their paper, Giang and Sui Pheng (2011) reviewed literature in the past four decades regarding the relationship between construction industry and economic growth. Five conclusions were drawn in their paper. First, there is a statistically significant positive relationship between economic growth and construction industry. On the other hand, this relationship requires further study in developed countries because this relationship appears to be more complicated in developed countries. Second, there is a consensus that the share of construction in gross national product (GNP) increases at a fast rate in developing economies and then decreases in mature economies. Figure 2.7 illustrates this with the Bon Curve. On the Bon Curve, less developed countries (LDC), newly industrialized countries (NIC), and advanced industrialized countries (AIC) are represented (Bon, 1992).





**Figure 2.7 – Bon Curve**

Third, it is unclear whether growth in share of construction industry in total gross domestic product (GDP) is a consequence or cause of economic growth. Fourth, demand for construction is derived from demand of other sectors. Thus, over expanding the construction industry potentially results in negative consequences if other sectors or countries are not ready to absorb the outputs of the construction industry. Lastly, the impacts of other industries' adaptive capacities on the construction industry are not fully understood. Building on their last conclusion and literature review thus far, it can be deduced that little is known about the impact of the construction industry's adaptive capacities (i.e, implementing AR of buildings) on other industries in the economy. This knowledge gap could be filled with economic models, such as regional economic modeling.

## **2.7 Regional economic models**

Several methods exist in the academic field of regional science to model the regional economy. These methods are Input-Output (IO) analysis, computable general equilibrium (CGE) models, social accounting matrices (SAM), econometric models, mathematical programming (MP), as well as gravity models (Cassey, Holland, & Razack, 2011; Isard et al, 1998; Okuyama, 2007; Partridge & Rickman, 2010; Rose, 1995; Rose & Liao, 2005). A brief overview of each method is as follows:

Input-output models can reveal the relationship between industries within a regional economy (i.e., IO analysis is a suitable framework for quantifying the changes to the regional economic system resulting of changing final demands from one or more sectors). Due to underlying assumptions of IO models, such as fixed price, fixed coefficients, and unbounded production capacity, they are suited for long run equilibrium of the economy (Cassey et al., 2011).

Computable general equilibrium (CGE) models are grounded primarily in microeconomic theory and lack a strong empirical basis. CGE models assume optimizing behaviours (e.g., utility maximization by consumers and profit maximization by producers) that result in an economic equilibrium. CGE model are an alternative to IO models with several differences. Unlike IO models, CGE models are non-linear and consider supply constraints and price changes (Cassey et al., 2011; Okuyama, 2007; Rose, 1995).

Social accounting matrices (SAMs) are “ a comprehensive disaggregated, consistent and complete data system that captures the interdependence that exist within a social economic system” (Isard et al., 1998, p.281). SAMs also form the basis for CGE model calibration.

Econometrics models are mathematical models grounded with economic theory and can be tested against empirical data utilizing statistical methods. In other words, econometric models determine whether economic theories can be used to explain empirical data. Three common application of econometric models are hypothesis testing, policy analysis, and forecasting (Isard et al., 1998).

Mathematical programs (MPs) maximize or minimize functions (linear or non-linear) subjected to constraints (linear or non-linear). For example, MP can be used to maximize profits, social gains, total income, per capital income, employment etc. (Isard et al., 1998; Rose & Liao, 2005).

Gravity models are based on the concept of Newton’s universal law of gravity. Regions are viewed as masses and as a result, the relationship between regions is analogous to the interaction between masses. General principles govern the interaction between the regions, thus affecting the behaviour of individual components within each region (Isard et al., 1998). Gravity models initially lacked a theoretical basis in economic or statistics, but numerous contributions over the past several decades have provided alternative foundations.

Although there are several methods that can be applied in regional economics, two of the mentioned methods are widely applied to regional economic impact analysis: IO and CGE analysis (Cassey, 2009; Cassey et al., 2011; Rickman, 2010; Rose, 1995). Since this research uses IO modeling, the following literature review will be limited to applications and techniques of IO modeling pertaining to the construction industry.

## **2.8 Application of Input-Output models**

IO modeling is a suitable approach for evaluating how an economic system will react to policy changes or external shocks (Dimitriou et al., 2015). There are countless studies on the applications of IO modeling in various field of academia. To name a few, Heslin and Hobbs (1990) assessed the economic impact that regulation changes in oil disposal had on the energy industry; Hewings, Schindler, & Israilevich (1997) established a relationship between airport capacity and economic growth; and Dimitriou et al. (2015) assessed the economic impacts of a mega infrastructure pipeline project in Greece. Dimitriou et al (2015) concluded that during the construction period, the project will directly generate 35-60 million euro, and indirectly generate 56-96 million euro; 700-1200 jobs are generated directly from the project, while 1120 – 1920 are indirectly generated in other sectors of the economy. During the operation period, the project is expected to directly generate 5-10 million euro in annual output, and 8-16 million euro indirectly; 80-200 new jobs are expected to be directly generated, and 130 – 320 new jobs generated indirectly.

One of the more popular recent applications of IO model is in disaster impact analysis (natural and terrorism). The “popularity of IO models for disaster related research is based mainly on the ability to reflect the interdependencies within a regional economy in detail for deriving higher-order effects, and partly on its simplicity” (Okuyama, 2007, p. 3). A well cited example is Hallegatte (2008), where a modified IO model was developed and applied to hurricane Katrina to assess the consequences of natural disasters and reconstruction that follows. By following his reference list, a vast repertoire of literature on economic impact assessments of disasters can be found. Another popular extension of IO models is in impact assessment of terrorist attacks on interdependent infrastructures. The Inoperability Input-Output Model (IIM) was developed “to describe how the impact of willful [terrorist] attacks can cascade through a system of interconnected infrastructures” (Crowther & Haines, 2005, p. 4). Disaster impacts, infrastructure investments, and regulation changes are a few examples of IO model applications in the larger collection of IO model literature. Other fields of study that specific IO modeling techniques are widely used in are environment and energy assessment (Miller & Blair, 2009). These techniques are called structural path analysis (SPA), structural decomposition analysis, and hypothetical extraction method.

Structural path analysis (SPA) is an IO modelling technique that

“... quantifies environmental transmission in the upstream process and identifies important paths with the highest environmental improvement potential by tracing back the intricate production chain.” (Hong, Shen, & Xue, 2016, p.2)

In their literature review, Hong et al.(2016) and Kaya (2017) identified that there are a lack of studies on SPA application to the construction industry. Literature on SPA application to the construction industry can be traced back to two primary authors: Graham J. Treloar, and Yuan Chang. Treloar determined embodied energy paths for the Australian building sector, and Chang analysed embodied energy use and environmental impact of the construction industry in China (Hong et al., 2016).

Structural decomposition analysis (SDA) is an analytical tool that analyses the “economic change by means of a set of comparative static changes in key parameters in an input-output table” (Rose & Casler, 1996). Applications of SDA include examining sources of change in international trade, technological change, energy, labour requirements, and development planning (Rose & Casler, 1996). This thesis’ literature review reveals that there is only one paper on SDA directly related to the construction industry. In their paper, Pietroforte et al., (2009) analyzed technological changes of the US construction industry between 1947 and 2002. The most important conclusion from their paper states that the impact of innovative technologies on the construction industry requires further study. To further expand, Pietroforte et al. (2009) recommends that structural changes in an economy resulting from the construction industry should consider:

“the impact of factors such as changes in the characteristics of construction projects (e.g. more bathrooms in residential projects), changes in architectural and engineering design, increased mechanization, the use of new materials and related substitution.” (p. 4)

This conclusion is important because it identifies the knowledge gap of AR in the construction industry from an economic impact perspective. Recall that AR is an end-of-life process that alters characteristics of construction projects, architectural and engineering design, and new materials and related substitutions.

The hypothetical extraction method (HEM), as its name implies, hypothetically extracts a sector from the input-output model to determine the impact to the economic system and intersectoral linkages because of this extraction (Song, Liu, & Langston, 2006). There are several other IO methods to determine sectoral linkages, but Miller and Lahr (2001) determined that the linkages from HEM are sufficient in determining the economic impact from extraction. Linkages can be separated into backward linkage and forward linkages. Backward linkage measures a industry’s dependency on other industries for inputs and forward linkage explains how a industry’s output is distributed to other sectors (Song et al., 2006). There are many linkage studies of other sectors in the economy, but there are few linkage studies on the construction industry. Ranko Bon and Roberto Peitroforte are the pioneers who first applied the IO model linkage concept to the construction industry (Bon, 1988; Lean, 2001; Song et al., 2006). Their studies concluded that the construction industry has weak forward linkages because only the maintenance and repair sub-industries produce goods that other industries can use. On the other hand, they found that the construction industry has strong backward linkages because the industry relies on many natural resources and inputs from other industries. There are a few studies that study the construction industry linkages with HEM. Song et al. (2006) used the HEM to determine role of the construction industry in the national economy for Australia, Canada, Denmark, France, Japan, Netherlands, and USA. Ren, Folmer, and Van der Vlist (2014) and Song, Liu, and Langston (2008) used HEM to determine the relationship between real-estate and construction industry for China, Australia, Canada, Denmark, France, Japan, Netherlands, and USA. These studies have found that the construction industry has strong backward linkages to the rest of the sectors in the economy. On the other hand, the construction industry’s forward linkages to other sectors in the economy are substantially smaller than its backward linkages. Ren et al. (2014) suggests that increasing demand for the construction industries may create large number of jobs due to its strong backward linkages with other sectors in the economy.

## **2.9 Summary – regional economic impact of adaptive reuse**

In summary, this literature review of AR and economics of the construction industry has indicated that there is a knowledge gap pertaining to the regional economic impacts of AR. Studies on AR have been conducted many times and there is an agreement that AR results in positive environmental benefits. There are claims of economic benefits associated with AR, yet there is lack of quantification of the economic benefits. At the

time of this literature review, studies that quantify these economic benefits are limited to cost analysis and no studies have extended beyond project economics to assess the regional economic impact of building AR. Since conducting literature review through AR yielded minimal insight on its regional economic impacts, the literature review continued through the perspective of economics. There are studies (although lacking) that examine the impacts of the construction industry on the rest of the economy. The scale of these studies is predominantly on the national level. Furthermore, there is a lack of studies that examines how changes (technical, regulatory, technological, innovations) within the construction industry propagate throughout the economy. Overall, the literature on AR of buildings has yet to expand beyond project economics into regional economics, and literature on economic impacts of the construction industry has not focused on regional economic impacts from its intersectoral changes. Hence, there is a knowledge gap regarding the regional economic impact of implementing AR of buildings as a strategy for functionally obsolete buildings.

### 3 Development of Input-Output model and fundamental concepts

Input-output (IO) modelling was used to determine the economic impacts of AR on the Region of Waterloo (RoW). This chapter describes the process of developing an IO model for RoW and provides background knowledge on concepts underlying IO analysis. Fundamental concepts presented here are drawn from Miller and Blair (2009); for more in-depth knowledge of IO modelling, refer to their book.

#### 3.1 The ordinary Input-Output model

The basis of IO modelling stems from the ordinary IO model developed by Wassily Leontief in the 1930's. IO models are developed from tables that record interindustry transactions, final demand, value-added, and total industry output. These tables are then converted into matrices and vectors, which are used to construct an IO model.

##### 3.1.1 Transaction matrix

An IO model consists of  $n$  linear equations that describe the relationships of  $n$  industries in an economic system. IO models are typically constructed using observed data for an economic region (national, regional, provincial, state, etc.). The necessary data for an IO model are the transactions of products and services between producing industries and purchasing industries. These transactions are presented in a transaction matrix,  $\mathbf{Z}$ , where the rows indicate the sellers and the columns indicate the buyers,

$$\mathbf{Z} = [z_{ij}] \quad (1)$$

where  $z_{ij}$  represents the monetary flow from industry  $i$  to  $j$ .

##### 3.1.2 Final demand and value added

In addition to inter-industrial industry transactions, there are sales that are external to the industries and are known as final demand. Final demand consists of industry sales to consumers, private investments, government, and exports. Final demand can be represented in a matrix or condensed into a vector. For the sake of brevity, the vector form is used. Denote the total final demand vector as  $\mathbf{f}$ ,

$$\mathbf{f} = \begin{bmatrix} f_i \\ \vdots \\ f_n \end{bmatrix} \quad (2)$$

where  $f_i$  represents the sales of each industry  $i$  to final demand. There is an additional vector that is necessary in the accounting of IO models and it is labelled the total value-added vector,  $\mathbf{w}$

$$\mathbf{w}' = [w_i \quad \cdots \quad w_n] \quad (3)$$

where  $w_i$  is the value-added input into industry  $i$ 's production. This vector accounts for non-industrial inputs to productions such as labour and wages, depreciation of capital, indirect business taxes/subsidies, and sometimes imports.

### 3.1.3 Total industry outputs

Let  $\mathbf{x}$ , be a vector of total industry outputs that is produced and sold (distributed) to the purchasing industries.

$$\mathbf{x} = \begin{bmatrix} x_i \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} x_j \\ \vdots \\ x_n \end{bmatrix} \quad (4)$$

The row sum,  $x_i$ , represents the total *output* of industry  $i$ , and is calculated as

$$x_i = \sum_{j=1}^n z_{ij} + f_i \quad (5)$$

On the other hand, the column sum,  $x_j$ , represents the total *input* to industry  $j$  and is calculated as

$$x_j = \sum_{i=1}^n z_{ij} + w_i \quad (6)$$

In matrix notation, total industrial outputs are calculated as follows,

$$\mathbf{x} = \mathbf{Z}\mathbf{i} + \mathbf{f} \quad (7)$$

or

$$\mathbf{x}' = \mathbf{i}'\mathbf{Z} + \mathbf{w}' \quad (8)$$

where  $\mathbf{i}$  and  $\mathbf{i}'$  are vectors of ones of appropriate size to achieve post and pre-multiplication (i.e., row and column sums). For eq (7),  $\mathbf{i}$  has dimensions  $(n \times 1)$  and for eq (8),  $\mathbf{i}'$  has dimensions  $(1 \times n)$ .

### 3.1.4 Technical coefficients and the Leontief inverse

From the transaction matrix, the matrix of technical coefficients,  $\mathbf{A}$ , can be derived

$$\mathbf{A} = [a_{ij}] \quad (9)$$

where  $a_{ij}$  represents the amount of input that is required by industry  $i$  to produce one unit of industry  $j$ 's output. Each  $a_{ij}$  is calculated as

$$a_{ij} = \frac{z_{ij}}{x_i} \quad (10)$$

In matrix notation, the technical coefficients are calculated as

$$\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1} \quad (11)$$

where  $\hat{\mathbf{x}}^{-1}$  is the inverse of the diagonalized total industry output vector,  $\mathbf{x}$ . (the hat symbolizes diagonalization of a vector into a matrix and subscript '-1' symbolizes the inverse operation of a matrix). Note that

$$\mathbf{A}\mathbf{x} = \mathbf{Z}\mathbf{i} \quad (12)$$

Rearranging eq (12) and substituting it into eq (7), an expression can be formulated and solved for  $\mathbf{x}$  resulting in the fundamental IO model for a single economic region.

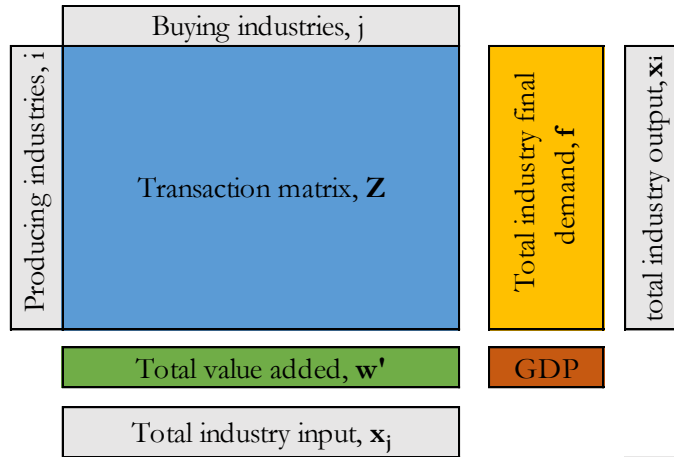
$$\begin{aligned} \mathbf{x} &= \mathbf{A}\mathbf{x} + \mathbf{f} \\ (\mathbf{I} - \mathbf{A})\mathbf{x} &= \mathbf{f} \\ \mathbf{x} &= (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \end{aligned} \quad (13)$$

The expression  $(\mathbf{I} - \mathbf{A})^{-1}$  is also known as the Leontief inverse (total requirements) matrix,  $\mathbf{L}$ , named after Wassily Leontief who pioneered IO modelling. Elements,  $l_{ij}$ , in the Leontief inverse matrix represents total inputs required for one unit of *final demand* (as opposed to  $a_{ij}$ , which represents the total inputs for one unit of *output*).

### 3.1.5 Accounting summary of ordinary Input-Output model

The accounting of an IO model is summarized in tabular format in Figure 3.1.





**Figure 3.1 – Accounting summary of ordinary Input-Output model**

Unfortunately, in Canada (and many countries around the world), IO data are not recorded in the ordinary format. Instead, the IO data are recorded in Make and Use format, also known as the commodity-by-industry approach.

### 3.2 Commodity-by-Industry approach to Input-Output modelling

The commodity-by-industry approach is used in many countries around the world because it accounts for the fact that industries produce secondary products, by-products, etc. As per Miller and Blair (2009, p.185), the underlying observation of the commodity-by-industry approach is that “industries use commodities to make commodities.” Two unique matrices in this approach are the Make and Use matrices.

#### 3.2.1 Use matrix

In the commodity-by-industry approach, the transaction matrix,  $\mathbf{Z}$ , is initially replaced with the Use matrix,  $\mathbf{U}$

$$\mathbf{U}_{(c \times i)} = [u_{ij}] \quad (14)$$

where  $u_{ij}$  is the value of purchases of commodity  $i$  by industry  $j$  and where the Use matrix has dimensions of commodity-by-industry ( $\mathbf{c} \times \mathbf{i}$ ).

The Use matrix has an equivalent to the ordinary technical coefficient matrix,  $\mathbf{A} = [a_{ij}]$ , and it is denoted as matrix  $\mathbf{B}$ . The equation for  $\mathbf{B}$  is calculated as

$$\mathbf{B}_{(c \times i)} = \mathbf{U}\hat{\mathbf{x}}^{-1} \quad (15)$$

Recall that  $\hat{\mathbf{x}}^{-1}$ , is the inverse of the diagonalized total industry output vector. Column  $j$  of the  $\mathbf{B}$  matrix represents the value of inputs of each commodity per dollar's worth of industry  $j$ 's output.

### 3.3 Import scrubbing Ontario Use matrix

The Canadian supply-use tables are published with imports included in the Use matrix,  $\mathbf{U}$ , with negative entries for imports added to the final demand vector, so that the sum of commodities used, and commodity final demand equals total commodity output.

$$q_i = \sum_{j=1}^n U_{ij}^{(\text{includes Imports})} + e_i^{(\text{includes import})} \quad (16)$$

Where  $q_i$  is total commodity output of industry  $i$   $e_i$  is final demand for commodity  $i$ . It is important to 'scrub' the use matrix of imports so that the impacts of the domestic economy can be analyzed. To import scrub the Ontario make and use data, first define  $\mathbf{u}$ , as a vector of total commodities used. In other words,  $\mathbf{u}$ , is the row sums of  $\mathbf{U}$ .

$$\mathbf{u} = \begin{bmatrix} u_i \\ \vdots \\ u_n \end{bmatrix} = \mathbf{U}\mathbf{i} \quad (17)$$

Define  $\mathbf{m}$ , as the vector of the final demand that is imports (expressed as negative values), and  $\mathbf{g}$ , as the vector of final demand that is not imports (final consumption expenditure, gross fixed capital formation, and exports) such that commodity final demand,  $\mathbf{e}$ , equals

$$\mathbf{e} = \mathbf{m} + \mathbf{g} \quad (18)$$

$$\begin{bmatrix} e_i \\ \vdots \\ e_n \end{bmatrix} = \begin{bmatrix} -m_i \\ \vdots \\ -m_n \end{bmatrix} + \begin{bmatrix} g_i \\ \vdots \\ g_n \end{bmatrix}$$

The typical import scrubbing method relies on the assumption of import similarity, where for each product, the proportion of imports and domestically produced goods is equal across all consuming sectors but may differ for each product. Import similarity can be expressed using a scaling factor given by vector  $\mathbf{r}$ , where each element is calculated as

$$r_i = \frac{m_i}{(u_i + g_i)} \quad (19)$$

In matrix notation,

$$\mathbf{r} = [(\widehat{\mathbf{u} + \mathbf{g}})^{-1}] \mathbf{m} \quad (20)$$

Recall that elements of  $\mathbf{m}$  are negatives, thus vector  $\mathbf{r}$  will also be negative.

The scrubbed transaction matrix is calculated as

$$\mathbf{U}_{scrubbed} = \mathbf{U} + \hat{\mathbf{r}}\mathbf{U} \quad (21)$$

Subsequently, the scrubbed technical coefficient matrix and value-added vector can be calculated as

$$\mathbf{w}'_{scrubbed} = \mathbf{i}' \mathbf{U}_{scrubbed} - \mathbf{x}' \quad (22)$$

Finally, the import scrubbed final demand is calculated as

$$\mathbf{e}_{scrubbed} = \mathbf{g} + \hat{\mathbf{r}}\mathbf{g} \quad (23)$$

Note that the second term,  $\hat{\mathbf{r}}\mathbf{g}$ , represents the vector of imports consumed directly by commodity final demand. After import scrubbing the Ontario use matrix, the make and use data were converted to the symmetric IO model format outlined in Chapter 3.3.4.

### 3.3.1 Make matrix

The Make matrix has dimensions of industry-by-commodity and shows how industries make commodities and is denoted as

$$\mathbf{V}_{(\mathbf{i} \times \mathbf{c})} = [v_{ij}] \quad (24)$$

where  $v_{ij}$  is the value of commodity  $i$  that is produced by industry  $j$ .

### 3.3.2 Total commodity/industrial output, value-added, and final demand

In the commodity-by-industry approach the total value-added vector is still denoted as  $\mathbf{w}'$ . However, the total final demand vector differs as it now represents the total final demand measured in commodities instead of industries. To make this distinction, total commodity final demand is denoted,  $\mathbf{e}$ , and total (industry) final demand from the ordinary IO model is still denoted,  $\mathbf{f}$ .

Total commodity output,  $\mathbf{q}$ , can be calculated by summing the industries that produce that commodity. In other words, total commodity outputs are the column sums of the Make matrix,  $\mathbf{V}$ . Alternatively, total commodity outputs can be found through row sums of the transpose of  $\mathbf{V}$ . In matrix notation  $\mathbf{q}$  is represented as

$$\mathbf{q} = (\mathbf{V}')\mathbf{i} \quad (25)$$

or

$$\mathbf{q} = \mathbf{U}\mathbf{i} + \mathbf{e} \quad (26)$$

Total industry output,  $\mathbf{x}$ , is calculated as

$$\mathbf{x} = \mathbf{V}\mathbf{i} \quad (27)$$

or

$$\mathbf{x} = \mathbf{i}'\mathbf{U} + \mathbf{w}' \quad (28)$$

### 3.3.3 Commodity output proportions

With  $\mathbf{q}$  and  $\mathbf{V}$  defined, the commodity output proportion matrix,  $\mathbf{D}$ , is calculated as

$$\mathbf{D}_{(c \times i)} = \mathbf{V}\hat{\mathbf{q}}^{-1} \quad (29)$$

where each element in  $\mathbf{D}$  represents the fraction of total commodity  $j$  output that was produced by industry  $i$ . The importance of  $\mathbf{D}$  is shown in the following section.

### 3.3.4 Developing ordinary Input-Output model from commodity-by-industry approach

Recall that the ordinary IO model is of the form  $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$ . The total industry output,  $\mathbf{x}$ , can be determined from the Make matrix,  $\mathbf{V}$ , but the  $\mathbf{A}$  matrix and  $\mathbf{f}$  vector are not directly given from the commodity-by-industry approach. There are multiple ways to reduce the commodity-by-industry approach to the ordinary IO model depending on whether demand is assumed to be industry or commodity driven, and whether the structure of the economy is assumed to be under commodity or industry technology. For this thesis, it is assumed that the Ontario economy is industry demand driven and is under *industry technology* assumption (i.e., that industries use commodities in fixed proportions). On the other hand, the *commodity technology* assumption assumes industries make commodities in fixed proportions, which is less consistent with a demand-driven IO model. Under these assumptions, a comparable matrix to the technical coefficient matrix,  $\mathbf{A}$ , can be calculated with  $\mathbf{D}$  and  $\mathbf{B}$ . Define  $\mathbf{A}_{I(i \times i)}$  as

$$\mathbf{A}_{I(i \times i)} = \mathbf{DB} \quad (30)$$

where the subscripts  $(i \times i)$  indicate matrix dimensions of industry-by-industry. With  $\mathbf{A}_{I(i \times i)}$ , the Leontief inverse (total requirements) matrix under industry technology is calculated as

$$\mathbf{L} = (\mathbf{I} - \mathbf{DB})^{-1} \quad (31)$$

The expression on the right-hand side is formally known as the *industry-by-industry total requirements matrix under industry technology*. For other versions of  $\mathbf{L}$ , refer to Table 5.4 and Table 5.5 of Miller and Blair (2009).

Total industry final demand,  $\mathbf{f}$ , can be calculated by pre-multiplying the total commodity final demand by  $\mathbf{D}$ .

$$\mathbf{f}_{(i \times 1)} = \mathbf{D}_{(i \times c)} \mathbf{e}_{(c \times 1)} \quad (32)$$

where the subscripts  $(i \times c)$  indicates matrix dimensions of industry-by-commodity. Finally, the ordinary IO model under the assumptions of industry demand driven economy and industry technology is represented as

$$\mathbf{x} = [(\mathbf{I} - \mathbf{DB})^{-1}] \mathbf{D} \mathbf{e} \quad (33)$$

### 3.3.5 Accounting summary of commodity-by-industry approach

The accounting of IO models in commodity-by-industry format is summarized in tabular form in Figure 3.2.

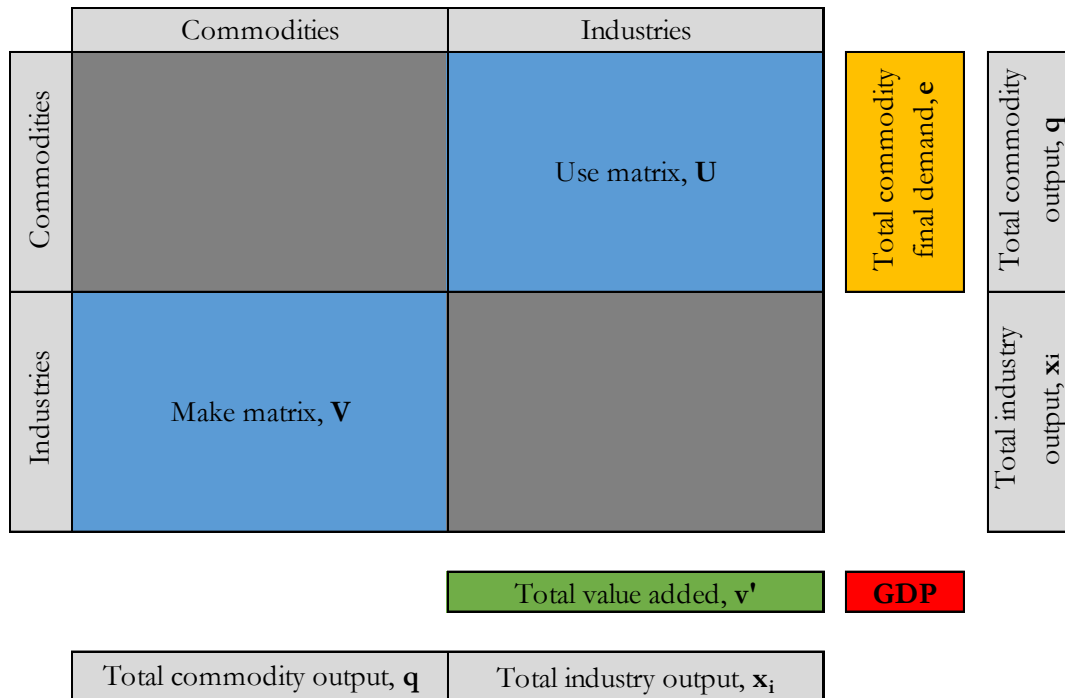


Figure 3.2 – Commodity-by-industry accounting summary

### 3.3.6 Ontario IO data

The Canadian IO data are recorded in supply and use tables (SUT), which are synonymous to make and use tables. The latest IO data (2014) was retrieved from Statistics Canada from Table 36-10-0478-01. This table provides IO data at the detailed level at the provincial and territorial level. The data were presented in comma-separated-value (csv) format, so the data was first organized into make, use, value-added, imports, exports, and final demand matrices. The dimensions of the matrices are outlined in Table 3.1.

Table 3.1 – Dimensions of matrices in 2014 make and use data

Matrices	Dimensions
Make (industry by commodity)	226 x 482
Use (commodity by industry)	482 x 226
Gross Value Added (value added type by industry)	8 x 226
Final Demand: Imports (commodity by imports)	481 x 14
Final Demand: Export (commodity by exports)	481 x 16
Final Demand: Final consumption expenditure and fixed gross capital formation (commodity by rest of final demand)	481 x 273

A list of row/column labels for commodities, industries, gross value added, and final demand is found in Appendix A. Once the data were organized into its respective matrices, the matrices in the commodity-by-industry approach were converted to the ordinary IO model format outline in Chapter 3.1.

The dimensions of Ontario commodity-by-industry matrices after conversion to IO model format are shown in Table 3.2.

**Table 3.2 – Dimensions of matrices used in IO model**

<b>Matrices</b>	<b>Dimensions</b>
<b>Transaction</b>	226 x 226
<b>Technical coefficient</b>	226 x 226
<b>Gross Value Added</b>	8 x 226
<b>Final Demand: Imports</b>	226 x 14
<b>Final Demand: Export</b>	226 x 16
<b>Final Demand: Final consumption expenditure and fixed gross capital formation</b>	226 x 273

Note that the gross value-added, and final demand matrices can be compressed into vectors (column sum for gross value added and row sums for final demands). The final demand matrices were compressed into a vector where the  $i^{\text{th}}$  element is the sum across row  $i$  of all final demand matrices. The household sector was endogenized before the Ontario IO model was regionalized.

### **3.4 Closing the IO model with respect to households**

Household expenditure plays a substantial part in the total final demand. Miller and Blair (2009) suggest household consumption contributes approximately 30% of the total final demand in many economic systems. Furthermore, household consumption is interrelated to the quantity of output of sectors. To elaborate, household consumers receive wages for their labour inputs into the production process of making outputs. Increasing the amount of output requires increasing the labour input and in return increases the earnings of consumers. However, increased earnings in household consumers encourages more spending, thus further increasing the outputs of sectors. Because of the interconnectedness of household expenditure, income, and industry output, household expenditure is often taken out of the final demand and re-introduced into the  $(n + 1)$  column of the intraregional transaction matrix. Additionally, household labour is taken out of value-added and re-introduced into the  $(n + 1)$  row of the intraregional transaction matrix. This process is known as “closing” the model with respect to households, which effectively makes their spending *endogenous*.

### 3.4.1 Household column

Let  $\mathbf{f}_{con\_ex}$  be the matrix of final consumer expenditure from the Ontario IO data. This portion of the final demand includes the household final consumption sectors. Recall that the raw data is in Make and Use format and needs to be converted to symmetric IO format to be compatible with the Ontario IO model. Also, recall that the raw data needs to be scrubbed of imports. Let  $\mathbf{f}_{con\_ex}^*$  be the new consumer expenditure matrix with the modifications mentioned above.

$$\mathbf{f}_{con\_ex}^* = \mathbf{D}\mathbf{f}_{con\_ex} + \hat{\mathbf{r}}\mathbf{D}\mathbf{f}_{con\_ex} \quad (34)$$

Recall  $\mathbf{r}$  is the import scrubbing scaling factor from eq (20) and is expressed in negative, and  $\mathbf{D}$  is the commodity output proportion matrix from eq (29).

The provincial import scrubbed industry-based household sectors were condensed to a vector,  $\mathbf{h}_C^p$  (superscript 'p' indicates province and subscript 'C' indicates column) and taken out from the import scrubbed final demand vector,  $\mathbf{f}_{scrubbed}$

$$\mathbf{f}^* = \mathbf{f}_{scrubbed} - \mathbf{h}_C^p \quad (35)$$

Where superscript \* indicates the household column removed from the provincial import scrubbed final demand vector.

### 3.4.2 Household row

The household row represents the salaries/income of household consumers. Salaries of consumers are found within the value-added vector and needs to be taken out for re-introduction into the transaction matrices.

Unlike the household columns, salaries can be taken from the raw data because the import scrubbing scaling factor  $\mathbf{r}$  was not applied directly to the value-added vector/matrix. Also, value-added is already presented by industries, so no further modifications are needed. Denote  $\mathbf{h}_{R,i}^p$  as the provincial household labour for industry  $i$  (superscript 'p' indicating provincial scale, and subscript 'R' indicating household row). Provincial household salaries were taken out from the value-added vector,

$$\mathbf{w}^* = \mathbf{w} - \mathbf{h}_R^p \quad (36)$$

Where superscript \* indicates the new value-added vectors with salaries and wages removed.



### 3.4.3 Reintroducing households into provincial transaction matrix

To completely close Ontario IO model with respect to households, several matrix and vector concatenations were required. Values for the  $(n+1)^{\text{th}}$  element of the output and final demand vectors and  $(n+1, n+1)^{\text{th}}$  cell of the provincial transaction matrix need to be introduced. The following partitions were created:

$$\bar{Z} = \begin{bmatrix} Z & h_C^p \\ h_R^p & 0 \end{bmatrix} \quad (37)$$

$$\bar{f} = \begin{bmatrix} f^* \\ 0 \end{bmatrix} \quad (38)$$

$$\bar{x} = \begin{bmatrix} x \\ (h_R^p) i \end{bmatrix} \quad (39)$$

$$\bar{w} = [w^* \quad (h_M^p) i] \quad (40)$$

where  $h_M^p$  are imports that go to household final consumption expenditure are calculated as the difference between sum of  $h_R^p$  and sum of  $h_C^p$ . Zeroes were concatenated to the  $(n+1, n+1)^{\text{th}}$  cell of the provincial transaction matrix and  $(n+1)^{\text{th}}$  element of provincial final demand. Row sum of the new household row was concatenated to regional output.

Finally, the closed provincial IO model is expressed as

$$\bar{x} = (I - \bar{A})^{-1} \bar{f} \quad (41)$$

### 3.5 Regional Input-Output model

This research is interested in developing a regional IO model for RoW in addition to an IO model for the province of Ontario. There are three ways to develop a regional model; full survey, non-survey, and partial/hybrid survey. A full survey will require asking regions variations of the basic question: ‘How much goods from sector  $i$  did you buy to produce your outputs?’ A full survey will result in a complete picture of the production technology within a region (i.e., true regional technical coefficients can be obtained). However, full surveys are costly and time consuming and the data may be outdated upon completion of the survey. It is more reasonable and typical to use regional input coefficients. These are different than regional technical coefficients, since they do not accurately describe the production technology of regional firms, but rather how local firms use local inputs. Regional input coefficients can be estimated using non-survey and partial survey techniques. Non-survey methods are used widely in regional IO models as they often use readily available regional economic activity data such employment, and income.

### 3.5.1 Single region model

Let  $z_{ij}^{rr}$ , be the dollar flow of goods from sector  $i$  in region  $r$  to sector  $j$  in region  $r$ . Let  $x_j^r$ , be the gross outputs of each sector in the region. Then, regional input coefficients,  $a_{ij}^{rr}$  can be calculated as

$$a_{ij}^{rr} = \frac{z_{ij}^{rr}}{x_j^r} \quad (42)$$

A regional input coefficient is defined as the difference between regional technical coefficient (total input required per dollar output) and regional import coefficient (import proportion of total input required per dollar output). Therefore, regional input coefficients describe the *regional portion* of the total input required per dollar output. In other words, it describes how inputs supplied by firms within the region are used to produce outputs by firms within the region. In matrix notation the regional input coefficient matrix is

$$A^{rr} = Z^{rr} (\hat{x}^r)^{-1} \quad (43)$$

Given final demand in region  $r$ ,  $f^r$ , impacts of regional production due to regional final demand changes can be computed as

$$x^r = (I - A^{rr})^{-1} f^r \quad (44)$$

Unfortunately, regional IO data for regions within the province of Ontario are not available. Thus, true regional input coefficients as shown in eq (42) cannot be calculated for regional modelling. To overcome this issue, estimation techniques were used to estimate regional input coefficients for the region of interest.

### 3.5.2 Estimating regional input coefficients with location quotients

Location quotients (LQs) are a non-survey technique for estimating regional input coefficients from national or provincial technical coefficients using readily published information on regional employment (most commonly), income, or output by industry. Location quotient techniques have been used widely in regionalization of IO models and there are several variations of location quotients (Miller & Blair, 2009).

#### 3.5.2.1 Regional employment data

The regional IO model was built upon the import scrubbed Ontario IO model. Regional employment data were used. Employment data was chosen for location quotient calculations as it is the most common choice of economic activity to use. Also, employment data by industry are readily available for the region of interest. Employment data for metropolitan areas in the province of Ontario were found in Table 14-10-0098-01 from

Statistics Canada. The employment data is presented by an aggregated list of industries (16 industries) compared to the list of industries in the Ontario IO model (32 industries). Appendix B shows the aggregation of industries of the employment data and their corresponding industries in the Ontario IO model. The chosen metropolitan areas and their industrial employment data is shown in Appendix C. Some metropolitan areas have suppressed employment data for the ‘Agriculture’, ‘Forestry, fishing, mining, quarrying, oil and gas’, and ‘Utilities’ because of the Statistics Act of Canada. Employment data that are suppressed are marked with ‘x.’ The censored employment data were estimated as follows.

First, the employment proportion of each non-censored industry of each metropolitan was calculated by dividing employment of each sector and each metropolitan by employment of that sector for Ontario. Then, the non-censored employment proportions were averaged, and the censored industries were assumed to take on the averaged employment proportions. Next the employment numbers for the censored data were estimated by multiplying the estimated employment proportion by the employment number of that industry for Ontario. Finally, the ‘Rest of ON’ employment data were calculated by summing the metropolitan employment numbers and subtracting the Ontario employment number by it. A two-region model is sufficient (discussed in Chapter 3.5.4) for the objectives of this thesis, so only employment data for the RoW was needed. Appendix B shows the employment numbers and proportions for the RoW.

### 3.5.2.2 Simple location quotient

The simple location quotient was the first LQ developed and provided a basis for the LQs developed afterwards. For this reason, the concept of simple LQ is presented before the selected LQ for this thesis is explained.

The simple location quotient applied to all purchasing sectors of industry  $i$  in region  $r$  is defined as

$$LQ_i^r = \left( \frac{x_i^r / x^r}{x_i^n / x^n} \right) \quad (45)$$

where  $x_i^r$  denotes gross output of industry  $i$  in region  $r$ ,  $x^r$  denotes total output of all sectors in region  $r$ ,  $x_i^n$  denotes gross output of industry  $i$  at the national level,  $x^n$  denotes total output of all sectors at the national level.

Regional input coefficients are calculated using simple LQ as follows

$$a_{ij}^{rr} = \begin{cases} (LQ_i^r) a_{ij}^n & \text{if } LQ_i^r < 1 \\ a_{ij}^n & \text{if } LQ_i^r \geq 1 \end{cases} \quad (46)$$

The simple LQ is viewed as a measure of a region's ability to supply goods of industry  $i$  to other sectors and final demand in the region. A simple  $LQ_i^r \geq 1$  indicates that industry  $i$  in region  $r$  is concentrated and is export orientated. On the contrary, a simple  $LQ_i^r < 1$  indicates that industry  $i$  in region is not concentrated  $r$  and is import orientated.

### 3.5.2.3 Cross industry quotients

Cross industry quotients (CIQ) were chosen because they allow for cell-by-by cell adjustment of the provincial technical coefficients rather than just row adjustments by simple location quotients. CIQ show the relative importance of both selling industry  $i$  and buying industry  $j$  in the region. Other location quotients such as the Flegg location quotients (FLQ) or augmented Flegg location quotients (AFLQ) are not selected for the simplicity of regional IO model development. To elaborate, both FLQ and AFLQ require calibration of a gamma term. An accurate calibration of this gamma term is not possible due to the lack of data available. Furthermore, validation of the two-region IRIO model with recommended value for gamma mentioned in Miller and Blair (2009) showed little to no improvement on model accuracy. The CIQ is calculated as

$$CIQ_{ij}^r = \left( \frac{e_i^r / e_i^n}{e_j^r / e_j^n} \right) \quad (47)$$

Also, CIQ for the aggregated 'Rest of Ontario' is needed for the two-region IRIO model (discussed in Chapter 3.5.4.1) and is calculated as

$$CIQ_{ij}^s = \left( \frac{e_i^s / e_i^n}{e_j^s / e_j^n} \right) \quad (48)$$

Where  $e_i^r$ ,  $e_j^r$ ,  $e_i^s$ ,  $e_j^s$ ,  $e_i^n$ , and  $e_j^n$  are the employment for RoW ( $r$ ), Rest of Ontario ( $s$ ), and Ontario ( $n$ ), in industries  $i$  and  $j$ , respectively. The cell-by cell adjustment is:

$$a_{ij}^{rr} = \begin{cases} (CIQ_{ij}^r) a_{ij}^n & \text{if } CIQ_{ij}^r < 1 \\ a_{ij}^n & \text{if } CIQ_{ij}^r \geq 1 \end{cases} \quad (49)$$

A  $CIQ_{ij}^r > 1$  means that all of  $j$ 's needs of input  $i$  can be supplied within the region. On the other hand,  $CIQ_{ij}^r < 1$  means that some of  $j$ 's input of  $i$  needs to be imported. Note that  $CIQ_{ij}^r = 1$  when  $i = j$  (on-

diagonal elements). This has been questioned in literature as noted in Miller and Blair (2009), so a further adjustment is made to the on-diagonal elements using simple LQ. The complete adjustment of  $\mathbf{A}$  matrix is

$$a_{ij}^{rr} = \begin{cases} (CIQ_{ij}^r) a_{ij}^n & \text{if } CIQ_{ij}^r < 1 \\ a_{ij}^n & \text{if } CIQ_{ij}^r \geq 1 \end{cases} \text{ for } i \neq j \quad (50)$$

$$a_{ij}^{rr} = \begin{cases} (LQ_i^r) a_{ij}^n & \text{if } LQ_{ij}^r < 1 \\ a_{ij}^n & \text{if } LQ_{ij}^r \geq 1 \end{cases} \text{ for } i = j \quad (51)$$

### 3.5.3 Estimating regional gross output

Statistics Canada does not have regional data for the output of industries, so the regional outputs requires estimation. Regional output can be estimated by multiplying employment proportions of each industry by the provincial outputs (Boero et al., 2018, Bachmann, 2014). Statistics Canada's annual employment by industry data were retrieved from Table 14-10-0098-01 (formerly CANSIM 282-0131) Below is an example to illustrate this concept. Let  $\boldsymbol{\varepsilon}^r = [\varepsilon_i^r]$  be a vector of employment proportion for industry  $i$  in region  $r$ , where  $\varepsilon_i^r$  is calculated as

$$\varepsilon_i^r = \frac{(\text{Employment in Region } r)_i}{(\text{Employment in Ontario})_i} \quad (52)$$

and given provincial output,  $\mathbf{x}$ , region output,  $\mathbf{x}^r$ , was estimated as

$$\mathbf{x}^r = \hat{\boldsymbol{\varepsilon}}^r \mathbf{x} = \begin{bmatrix} \varepsilon_1^r x_1 \\ \vdots \\ \varepsilon_n^r x_n \end{bmatrix} \quad (53)$$

A single region model assumes that all inputs into production are reflected in the intraregional matrix  $\mathbf{A}^{rr}$ . This assumption is unrealistic because regions are interconnected with each other through trade. Single region models fail to explain the connectiveness of region. Thus, an interregional approach was taken.

### 3.5.4 Interregional approach to regional Input-Output models

Interregional input output (IRIO) models can consists of two or more regions. For this thesis, a two-region IRIO model was developed. An IRIO model consisting of all regions in Ontario is ideal but was not possible for this thesis due to the lack of data needed. Furthermore, a two-region IRIO model is enough for the purposes of this thesis because only RoW is of interest.

Let region  $r$  be RoW and let region  $s$  be 'Rest of Ontario' (shortened to Rest of ON). Then, a two-region IRIO model requires the following intra- and interregional data

$$\mathbf{x}^r = [x_i^r] \quad (54)$$

$$\mathbf{x}^s = [x_i^s] \quad (55)$$

$$\mathbf{Z}^{rr} = [z_{ij}^{rr}] \quad (56)$$

$$\mathbf{Z}^{ss} = [z_{ij}^{ss}] \quad (57)$$

$$\mathbf{Z}^{rs} = [z_{ij}^{rs}] \quad (58)$$

$$\mathbf{Z}^{sr} = [z_{ij}^{sr}] \quad (59)$$

Where  $\mathbf{Z}^{rs}$  is the matrix of transactions from industry  $i$  in region  $r$  to industry  $j$  in region  $s$ , and  $\mathbf{Z}^{sr}$  is the matrix of transaction from industry  $i$  in region  $s$  to industry  $j$  in region  $r$ . In other word,  $\mathbf{Z}^{rs}$  represent exports from region  $r$  and imports to region  $s$  and vice versa for  $\mathbf{Z}^{sr}$ .

Given inter- and intraregional transactions the regional input coefficients for region  $s$  are

$$a_{ij}^{ss} = \frac{z_{ij}^{ss}}{x_j^s} \quad (60)$$

and the interregional trade coefficients were calculated the same way, except the denominators are gross outputs of the receiving region.

$$a_{ij}^{rs} = \frac{z_{ij}^{rs}}{x_j^s} \quad (61)$$

$$a_{ij}^{sr} = \frac{z_{ij}^{sr}}{x_j^r} \quad (62)$$

In matrix notation, the regional input coefficient for region  $s$  and interregional trade coefficients are

$$\mathbf{A}^{ss} = \mathbf{Z}^{ss}(\hat{\mathbf{x}}^s)^{-1} \quad (63)$$

$$\mathbf{A}^{rs} = \mathbf{Z}^{rs}(\hat{\mathbf{x}}^s)^{-1} \quad (64)$$

$$\mathbf{A}^{sr} = \mathbf{Z}^{sr}(\hat{\mathbf{x}}^r)^{-1} \quad (65)$$

#### 3.5.4.1 Basic Structure of two-region interregional Input-Output model

Given the necessary data, the next step in developing a two-region IRIO model is to organize the regional matrices and vectors into the following expression

$$\mathbf{x}^{IRIO} = (\mathbf{I} - \mathbf{A}^{IRIO})^{-1} \mathbf{f}^{IRIO} \quad (66)$$

where

$$\mathbf{x}^{IRIO} = \begin{bmatrix} \mathbf{x}^r \\ \mathbf{x}^s \end{bmatrix} \quad (67)$$

$$\mathbf{f}^{IRIO} = \begin{bmatrix} \mathbf{f}^r \\ \mathbf{f}^s \end{bmatrix} \quad (68)$$

$$\mathbf{I} = \begin{bmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{bmatrix} \quad (69)$$

$$\mathbf{A}^{IRIO} = \begin{bmatrix} \mathbf{A}^{rr} & \mathbf{A}^{rs} \\ \mathbf{A}^{sr} & \mathbf{A}^{ss} \end{bmatrix} \quad (70)$$

Chapter 3.5.2 and 3.5.3 showed that regional input coefficients and regional output can be estimated using cross industry location quotients and employment data. The procedure outline Chapter 3.5.2 and 3.5.3 were followed to produce regional input coefficients ( $\mathbf{A}^{rr}$  and  $\mathbf{A}^{ss}$ ) and regional outputs ( $\mathbf{x}^r$  and  $\mathbf{x}^s$ ) for RoW and Rest of ON. What remain is the calculation of interregional trade coefficients ( $\mathbf{A}^{sr}$  and  $\mathbf{A}^{rs}$ ) and two-region IRIO final demand,  $\mathbf{f}^{IRIO}$ .

### 3.5.5 Estimating interregional trade matrices, and regional final demand and output vectors

Given regional input coefficients of region  $s$ , interregional trade coefficients for region  $r$  (RoW) to region  $s$  (Rest of ON) were calculated

$$a_{ij}^{rs} = a_{ij} - a_{ij}^{ss} \quad (71)$$

Recall  $a_{ij}$  are technical coefficients eq (10) from the Ontario IO model. Similarly, given regional input coefficients of region  $r$ , interregional trade coefficients for region  $s$  (Rest of ON) to region  $r$  (RoW) were calculated

$$a_{ij}^{sr} = a_{ij} - a_{ij}^{rr} \quad (72)$$

After calculating the coefficients and organizing them into the two-region IRIO coefficient matrix,  $\mathbf{A}^{IRIO}$ , inter – and intraregional transaction matrices were calculated as

$$\mathbf{Z}^{IRIO} = \begin{bmatrix} \mathbf{Z}^{rr} & \mathbf{Z}^{rs} \\ \mathbf{Z}^{sr} & \mathbf{Z}^{ss} \end{bmatrix} = \begin{bmatrix} \mathbf{A}^{rr} & \mathbf{A}^{rs} \\ \mathbf{A}^{sr} & \mathbf{A}^{ss} \end{bmatrix} \begin{bmatrix} \mathbf{x}^r & \mathbf{0} \\ \mathbf{0} & \mathbf{x}^s \end{bmatrix} \quad (73)$$

Then regional final demand vectors were calculated and partitioned into a two-region IRIO final demand vector

$$\mathbf{f}^{IRIO} = \begin{bmatrix} \mathbf{f}^r \\ \mathbf{f}^s \end{bmatrix} = \begin{bmatrix} \mathbf{x}^r - (\mathbf{Z}^{rr} \mathbf{i} + \mathbf{Z}^{rs} \mathbf{i}) \\ \mathbf{x}^s - (\mathbf{Z}^{sr} \mathbf{i} + \mathbf{Z}^{ss} \mathbf{i}) \end{bmatrix} \quad (74)$$

Finally, the two-region IRIO output vector was calculated with eq (54) to eq (59) and the two-region IRIO model was complete.

### 3.5.6 Verification of two-region IRIO model

Verification of the two-region IRIO model was done by comparing the regional output vectors,  $\mathbf{x}^r$  and  $\mathbf{x}^s$ , calculated in Chapter 3.5.3 (recall  $\mathbf{x}^r$  and  $\mathbf{x}^s$  were calculated by downscaling provincial output vector by employment data) and the two-region output vector,  $\mathbf{x}^{IRIO}$ , in Chapter 3.5.5 (recall  $\mathbf{x}^{IRIO}$  was calculated with eq (66)). If all the steps were executed correctly the following accounting balances should be met within an acceptable error (e.g. < 1%)

1.  $\mathbf{x}^{IRIO} = (\mathbf{I} - \mathbf{A}^{IRIO})^{-1} \mathbf{f}^{IRIO} \cong \begin{bmatrix} \mathbf{x}^r \\ \mathbf{x}^s \end{bmatrix} = \begin{bmatrix} \hat{\mathbf{x}}^r \\ \hat{\mathbf{x}}^s \end{bmatrix}$
2.  $\mathbf{x} \cong \mathbf{x}^r + \mathbf{x}^s$
3.  $\mathbf{f} \cong \mathbf{f}^r + \mathbf{f}^s$

The two-region IRIO model was checked and it satisfied the above-mentioned accounting balances. Next, analysis techniques such as hypothetical extraction, backward and forward linkages, and technology shock were conducted and are outlined in Chapter 3.6 and beyond.

### 3.5.7 Validation of regional household consumption

The two-region IRIO model was validated against regional population data. Recall in the development of the two-region IRIO model, output was down-scaled using regional employment data, and then final demand was back calculated. Another approach to regionalization would be to down-scale final demand by regional data and then back calculate output. This approach may require more data to accurately down scale the portion of final demand for exports and capital formation. However, household consumption can be accurately down scaled using regional population data. Thus, the household consumption vector determined from Chapter 3.4.1 was validated against the second approach where provincial household consumption was down scaled using regional population. The Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) are, 78 779 and 272 658 respectively for both RoW and Rest of ON. Since total household consumptions for RoW and Rest of ON are 11 646 793 and 301 402 817, respectively, the values for MAE and RMSE indicates agreement between the two approaches. The average relative percent error for RoW and Rest of ON are 14.7% and 0.56%, respectively. Bar charts comparing final demand between these two approaches are shown in Appendix D.



### 3.6 Hypothetical extraction and linkages

#### 3.6.1 Hypothetical Extraction

Hypothetical extraction is a method to measure an industry's importance or total linkage to the economy. An industry's total linkage is determined by 'removing' the industry from the economy and calculating the resulting decrease in value of gross output. In the IO model framework, the total linkage of industry  $j$  is found by changing  $j$ 's row and columns to zeroes in the technical coefficient matrix,  $\mathbf{A}$ , and the  $j$ 's row to zero in the final demand. Let  $\bar{\mathbf{A}}_{(j)}$ , be the new technical coefficient matrix of the economy with subscripts '(j)' indicating rows and columns of industry  $j$  changed to zeroes. Let  $\bar{\mathbf{f}}_{(j)}$ , be the new final demand vector with industry  $j$ 's row changed to zero. Then, the decrease in value of gross output is modeled with

$$\bar{\mathbf{x}}_{(j)} = (\mathbf{I} - \bar{\mathbf{A}}_{(j)})^{-1} \bar{\mathbf{f}}_{(j)} \quad (75)$$

Then, estimate of the total decrease in economic activity in percentage value is calculated as

$$\bar{T}_j = 100\% \times \left[ \frac{(\mathbf{i}' \mathbf{x} - \mathbf{i}' \bar{\mathbf{x}}_{(j)})}{\mathbf{i}' \mathbf{x}} \right] \quad (76)$$

Where  $\mathbf{x}$ , is the base case output with all industries included. Hypothetical extraction of 'Residential building construction' and 'Non-residential building construction' were conducted to the intraregional input coefficient matrices ( $\bar{\mathbf{A}}^{rr}$  and  $\bar{\mathbf{A}}^{ss}$ ) of the closed two-region IRIO model. Total linkages of these industries were calculated for Ontario, RoW and Rest of ON.

#### 3.6.2 Backward linkages

Hypothetical extraction can also be used to calculate backward and forward linkages of industries following a parallel approach. Backward linkage is a measurement of economic pull of an industry or in other words, the strength of industry  $j$ 's dependence on interindustry inputs to produce industry  $j$ 's output. Backward linkages are calculating by replacing column  $j$  of the  $\mathbf{A}$  matrix with zeroes. Let  $\bar{\mathbf{A}}_{(cj)}$  be the new matrix where subscripts '(cj)' indicating that column  $j$  is replaced with zeroes. Then new values of output are modelled as

$$\bar{\mathbf{x}}_{(cj)} = (\mathbf{I} - \bar{\mathbf{A}}_{(cj)})^{-1} \mathbf{f} \quad (77)$$

and the normalized element-by-element backward linkages of industry  $j$  on industry  $i$  is

$$bl_{(cj)i} = 100\% \times \left[ \frac{(x_i - \bar{x}_{(cj)i})}{x_j} \right] \quad (78)$$

Backward linkages were calculated for ‘Residential building construction’ and ‘Non-residential building construction’ for Ontario, RoW and Rest of ON.

### 3.6.3 Forward linkages

Similarly, hypothetical extraction can be used to calculate the forward linkages of industries in the IO framework. Forward linkage is a measure of the strength of economic push that industry  $j$  has on the rest of the economy. In other words, forward linkage measures the dependencies of other industries as buyers of industry  $j$ 's outputs.

Miller and Blair (2009) suggests that forward linkages are better calculated using an alternative to the input-output model developed by Ghosh. This model is supply driven in contrasts to the demand driven model developed by Leontief. In calculating forward linkages, the *direct output coefficient matrix*,  $\mathbf{B}$ , is used in place of the *direct input coefficient matrix*,  $\mathbf{A}$ . To differentiate Ghosh's  $\mathbf{B}$  matrix and the  $\mathbf{B}$  matrix presented in eq (15) in Chapter 3.2, Ghosh's direct output coefficient matrix will be referred to as  $\mathbf{B}_{ghosh}$ .

$\mathbf{B}_{ghosh}$  is calculated similarly to  $\mathbf{A}$ , except that the interindustry transaction matrix,  $\mathbf{Z}$ , is pre-multiplied by  $\mathbf{x}$  instead of post-multiplication as seen in calculating  $\mathbf{A}$ . In other words,  $\mathbf{B}_{ghosh}$  is calculated by dividing each row element of  $\mathbf{Z}$  by the gross output associated with that row. In matrix notation this is calculated as

$$\mathbf{B}_{ghosh} = \hat{\mathbf{x}}^{-1} \mathbf{Z} \quad (79)$$

Forward linkage is calculated by replacing the row of industry  $j$  with zeroes and calculating the new values of gross output. This calculation is completed as

$$\bar{\mathbf{x}}'_{(rj)} = \mathbf{v}' (\mathbf{I} - \bar{\mathbf{B}}_{(rj)})^{-1} \quad (80)$$

Again, the subscripts '(rj)' indicates that the row of industry  $j$  is replaced with zeroes. Then, the normalized element-by-element forward linkage of industry  $j$  on industry  $i$  is

$$fl_{(rj)i} = 100\% \times \left[ \frac{(x_i - \bar{\mathbf{x}}'_{(rj)i})}{x_j} \right] \quad (81)$$

Forward linkages were calculated for ‘Residential building construction’ and ‘Non-residential building construction’ for Ontario, RoW, and Rest of ON.

### 3.7 Use matrix and final demand change

A major use of IO models is to study economic impacts as a result of changes to the structure of the economy (i.e., changes to output, final demand, value added, and technology (technical coefficients)). For example, IO models can be used to simulate impacts of investing in a mega infrastructure project on GDP and wages in an economy. Impacts as a result of changes in the structure of an economy can be simulated with an IO model by changing the  $u_{ij}$  values in the  $\mathbf{U}$  matrix. For this thesis, the structure of inputs (herein referred to as “recipe”) of the construction industry is shocked to reflect the impacts of AR of buildings on the economy. In simpler terms, the usage recipe of an industry refers to its column in the  $\mathbf{U}$  matrix as the column indicates the quantity of each ‘ingredient’ that goes into producing \$1 of output for that industry. Furthermore, since import scrubbing was applied directly to the Use matrix, recipe changes were applied to the Use matrix prior to import scrubbing. This was done so that the effect of AR on imported commodities is accounted for.

It was determined, through consultation of Statistics Canada, that among all the construction related industries in the IO model, AR of buildings would affect the ‘Residential building construction’ and ‘Non-residential building construction’ industries. Recipe changes to these industries were not applied simultaneously; rather they were applied separately to represent various scenarios.

Denote  $\alpha$  as the vector of input changes in decimal format where negative values represent decreases and positives values represents increases. For example,  $\alpha_i = 0.5$  indicates a 50% savings in commodity use, and  $\alpha_i = -0.5$  means 50% increase in use of commodity  $i$ . Denote  $\theta$ , as a column vector where elements 1 to  $n$  are elements from the column vector of the industry of interest in the  $\mathbf{U}$  matrix and where element  $n+1$  is household labour from the value-added vector of the industry of interest. Denote  $\beta$ , as a scalar value that represents the percentage of the industry that the changes apply to. For example, if 50% of the ‘Residential building construction’ industry is capable of AR, then  $\beta = 0.5$ . Then, changes to the industry recipe were calculated by:

$$\theta^{new} = [i - \widehat{(\beta \alpha)}] \theta \quad (82)$$

where the hat indicates diagonalization of the vector contained in the square brackets, and where  $i$  is a vector of ones with same dimension as  $\alpha$  and  $\theta$ . Equation (82) is developed such that if  $\beta = 0$ , then no changes are made to the Use matrix. Note that the total commodity value reduced from changing industry  $j$ 's recipe is

reallocated to value added. This is because the savings in commodity inputs are treated as profits to industry  $j$ , which is accounted for in value-added. Also, increases to household labour are accompanied by decreases in other value added. This implies that industry  $j$  earns less profit (or must earn lower returns on capital) to afford increased wages to labour. The new Use matrix and value-added vector reflecting AR of residential or non-residential building construction industries are:

$$\mathbf{U}_{new} = \begin{bmatrix} u_{ii} & \cdots & \theta_{ij} & \cdots & u_{in} \\ \vdots & \ddots & & & \vdots \\ u_{ji} & & \theta_{jj} & & u_{jn} \\ \vdots & & & \ddots & \vdots \\ u_{ni} & \cdots & \theta_{nj} & \cdots & u_{nn} \end{bmatrix} \quad (83)$$

$$\mathbf{w}'_{new} = [w_i \quad \cdots \quad \theta_{n+1,j} \quad \cdots \quad w_n] \quad (84)$$

Note that a portion of the commodities used by industries in the provincial Use tables are imported. Since AR recipe changes are applied before import scrubbing, reducing the values in the Use table implies reduction in the use of both domestic and imported commodities. Thus, it is also necessary to reduce imports in the import vector,  $\mathbf{m}$ , to conserve gross domestic product. Let  $\boldsymbol{\theta}_{AR}$  denote the reductions in the Use matrix resulting from recipe changes for the industry of interest, let  $\mathbf{m}_{AR}$  denote the portion of imports that is from  $\boldsymbol{\theta}_{AR}$ , and let  $\mathbf{m}_{new}$  be the new imports vector after AR recipe changes. Then,  $\boldsymbol{\theta}_{AR}$  is calculated as

$$\boldsymbol{\theta}_{AR} = \beta \hat{\alpha} \boldsymbol{\theta} \quad (85)$$

and  $\mathbf{m}_{AR}$  is calculated as

$$\mathbf{m}_{AR} = \hat{\mathbf{r}}_{existing} \boldsymbol{\theta}_{AR} \quad (86)$$

Recall that  $\mathbf{r}$  is the import scrubbing scaling factor from eq (20) and has elements with negative values. The subscript ‘existing’ indicates the import scrubbing scaling factor for the base case. Finally,  $\mathbf{m}_{new}$  is calculated as

$$\mathbf{m}_{new} = \mathbf{m} - \mathbf{m}_{AR} \quad (87)$$

Recipe changes to the ‘Residential building construction’ and ‘Non-residential building construction’ industries were conducted separately. With the new Use matrix, import vector, and value-added vector, a symmetric IO model reflecting AR of buildings was developed following the steps outline in Chapters 3.2 to 3.4.

Like the changes made to Use matrix and import and value-added vectors, changes can be made to final demand. The same concept was applied to change the final demand vector of the provincial IO model, except  $\alpha$  represents the vector for final demand change. Hence, the new final demand reflecting AR of buildings is calculated as:

$$f^{new} = [i - \widehat{(\beta \alpha)}]f \quad (88)$$

### 3.8 Energy use by industry

Energy use data by industry for Canada were obtained from Statistics Canada Table 38-10-0096-01 (formerly CANSIM 153-0113) for the year 2014. The data presented is a vector of total energy use by industries measured in terajoules (TJ). Energy intensities of each industry were calculated as

$$E_i = \frac{(total\ energy\ use)_i}{x_i} \left[ \frac{TJ}{\$} \right] \quad (89)$$

The industry classifications of this table are an aggregated version of the detailed industry classification of the IO model, so concordance of these classifications was done prior to applying the energy use data to the IRIO model. A table of concordance is shown Appendix C. Furthermore, it was assumed that the energy intensities of Ontario are equal to that of Canada's. Note that, there are several industries with unreported data due to the Statistics Act of Canada. The energy intensities of these industries were estimated by allocating the difference in total reported energy use and total energy use (calculated from table) using output proportions. For example, the reported total energy use for industries and households is 11,637,461 TJ, but the sum of energy use within the table is 11,379,978 TJ. Thus, the difference is 257,483 TJ, which is assumed to be combined energy use of the censored industries. This difference (257,483 TJ) was allocated proportionally to the censored industries.

With the vector of energy intensities calculated, energy use by industry was simply calculated by element-by-element multiplication of the output vector and energy intensity vector. In matrix notation:

$$\widehat{E}x = \begin{bmatrix} E_i & & \mathbf{0} \\ & \ddots & \\ \mathbf{0} & & E_n \end{bmatrix} \begin{bmatrix} x_i \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} E_i x_i \\ \vdots \\ E_n x_n \end{bmatrix} \quad (90)$$

### 3.9 Jobs by industry

Changes to employment by industry were determined by multiplying the changes in output by an employment intensity vector. Employment data from Statistics Canada are aggregated into 16 industries, so the detailed industry classification was first aggregated accordingly. The 226 industries in the detailed classification were

aggregated to 16 industries using a concordance matrix (Bachmann et al., 2015). Let  $\mathbf{K}$  be the concordance matrix, then pre-multiplication of the detailed output vector by  $\mathbf{K}$  determines the aggregated output vector:

$$\mathbf{x}_{agg} = \mathbf{K} \mathbf{x} \quad (91)$$

After obtaining  $\mathbf{x}_{agg}$ , employment intensities were calculated by dividing each element of the aggregated industries employment data by its corresponding aggregated industry output. In matrix notation:

$$\boldsymbol{\epsilon} = \boldsymbol{\lambda} \widehat{\mathbf{x}_{agg}}^{-1} \quad (92)$$

where  $\boldsymbol{\lambda}$  is the vector of aggregated industry employment and  $\boldsymbol{\epsilon}$  is in units of employment per dollar of industry output. Similarly, changes in employment at the aggregated industry level can be found by pre-multiplying the diagonalized employment intensity vector by a vector of output changes. Consequently, total changes in employment can be found by summing the vector of job changes.

### 3.10 Toy model

The methodology implemented in developing a two-region IRIO model was tested on a hypothetical small-scale economy with two commodities and two industries (toy model). The model development steps were applied to the toy model to ensure the steps taken satisfies economic principles and accounting balances. Also, the development of this toy model served as a learning tool for the intricacies of IO modeling. Toy models were developed to mirror the existing case and AR scenarios used in this study. The lessons learnt from the toy models and the toy models can be found in Appendix E.

## **4 Results and discussion**

Before any analysis was done with the two-region IRIO model, the construction industries affected by adaptive reuse (AR) were first determined. Through consultation with a senior economic analyst at Statistics Canada, it was determined that AR of buildings is embedded into the ‘Residential building construction,’ and ‘Non-residential building construction’ industries (Trau, 2018). From herein, these two industries will be referred together as ‘building industries.’ With this knowledge, consequent analyses focused on these two industries.

The results chapter is structured as follows. Chapter 4.1 discusses the scenarios of AR of buildings that have been analyzed. Chapter 4.2 discusses the energy use and employment intensities for Ontario and RoW. Chapter 4.3 presents the economic profile of Ontario, and the results of scenario analyses for Ontario. Chapter 4.4 discusses the economic profile of Region of Waterloo (RoW), and the results of scenario analyses for RoW. Lastly, Chapter 4.5 summarizes the results.

### **4.1 Scenario analysis of adaptive reuse of building construction industries**

Scenarios for the analysis of AR of building construction industries are broken down into two main sets. One set of scenarios represents the situation where final demand for residential and non-residential buildings is fixed. The other set of scenarios represents the situation where final demand for these buildings increase. Table 4.1 below outlines the names and description for each scenario.

**Table 4.1 – Scenario names and description**

<b>Scenario Name</b>	<b>Description</b>
Basic	Adaptive reuse of superstructure and substructure, includes changes to engineering services, wages and salaries, and truck transportation. 0% reuse of interior non-structural components, and 0% increase in final demand.
10%	'Basic' scenario plus 10% adaptive reuse of interior non-structural components
45%	'Basic' scenario plus 45% adaptive reuse of interior non-structural components
90%	'Basic' scenario plus 90% adaptive reuse of interior non-structural components
f2.5_basic	'Basic' scenario plus 2.5% increase to final demand for adaptive reuse of residential or non-residential buildings
f2.5_10	'10%' scenario plus 2.5% increase to final demand for adaptive reuse of residential or non-residential buildings
f2.5_45	'45%' scenario plus 2.5% increase to final demand for adaptive reuse of residential or non-residential buildings
f2.5_90	'90%' scenario plus 2.5% increase to final demand for adaptive reuse of residential or non-residential buildings
f5_basic	'Basic' scenario plus 5% increase to final demand for adaptive reuse of residential or non-residential buildings
f5_10	'10%' scenario plus 5% increase to final demand for adaptive reuse of residential or non-residential buildings
f5_45	'45%' scenario plus 5% increase to final demand for adaptive reuse of residential or non-residential buildings
f5_90	'90%' scenario plus 5% increase to final demand for adaptive reuse of residential or non-residential buildings
f10_basic	'Basic' scenario plus 10% increase to final demand for adaptive reuse of residential or non-residential buildings
f10_10	'10%' scenario plus 10% increase to final demand for adaptive reuse of residential or non-residential buildings
f10_45	'45%' scenario plus 10% increase to final demand for adaptive reuse of residential or non-residential buildings
f10_90	'90%' scenario plus 10% increase to final demand for adaptive reuse of residential or non-residential buildings

#### **4.1.1 Fixed demand for adaptively reused buildings – Basic scenario**

Recall from Chapter 2 that by the definition of AR of buildings, at minimum the building's superstructure and substructure remains intact. This definition forms the basis for the 'Basic' scenario. Through literature of



AR and deconstruction of buildings, it was found that, in general, AR of buildings results in reduced transportation of construction waste disposal, and increased labour and engineering/architectural design (Chini & Bruening, 2003; Coelho & De Brito, 2011; Gorgolewski, 2008; Laefer & Manke, 2008; Shipley et al., 2006; Tatiya et al., 2017)

At the same time, Ontario’s auditor general found that approximately a sixth of buildings owned by the province are vacant (Crawley, 2017). This finding applies only to publicly owned buildings, not privately owned. Thus, a rough estimation of AR market share ( $\beta$ ) was done to include privately owned buildings. The lower-bound market share of buildings (residential and non-residential) that are candidates for AR is estimated to be 20% (i.e.,  $\beta = 0.2$  in the notation from Chapter 3.7). On the contrary, Canada’s 2016 Infrastructure Report Card found that 5%, 12%, and 20% of municipal buildings are in ‘very poor,’ ‘poor,’ and ‘fair’ conditions, respectively. Again, these numbers are reported on publicly owned buildings. Assuming, that ‘very poor,’ ‘poor,’ and ‘fair’ buildings are candidates for AR, the realistic upper bound market share of buildings that may be adaptively reused is estimated to be 40% (i.e.,  $\beta = 0.4$  in the notation from Chapter 3.7). Also, an idealistic upper bound market share of 60% and 80% ( $\beta = 0.6$  and  $\beta = 0.8$ ) is used as an extension to the analysis.

A case study on the AR of the Region of Waterloo’s County Courthouse was done by Sanchez, Esfahani, & Haas (2019). In their case study, a comparison of the life cycle costs and environmental impacts of adaptively reusing the courthouse versus demolition and reconstruction of a new building were examined. The case study was limited in scope to the AR of the building’s superstructure and substructure (i.e., all the internal non-structural components of the building were excluded). The quantity take-offs from Sanchez’s BIM model were used to calculate the dollars saved on concrete and steel materials. Table 4.2 summarizes the estimated material costs for steel and concrete in the Region of Waterloo County Courthouse case study.

**Table 4.2 – Concrete and steel material cost estimation**

Material	New Construction	Adaptive Reuse	Savings, %
Concrete	\$252,631	\$48,350	80.86
Steel	\$841,775	\$180,092	78.61

In addition, Brito and Coelho (2011) found that disposal costs (including transportation) are reduced by about 20% when implementing deconstruction over demolition of a building. Gorgolewski (2008) found that design fees for AR of buildings may increase 20% to 40%. Thus, ‘Architectural, engineering and related services’ commodity was increased by 20% in the Use matrix. In their literature review, Coelho and De Brito (2011) found a case study of deconstruction versus demolition that determined the labour cost of deconstruction of buildings are approximately 20% higher than demolition. In a case study, Dantata, Touran,

and Wang (2005) found that deconstruction labour occupied 56% of the project cost, while demolition labour occupied 32% project cost. Furthermore, Dantata et al. (2005) conducted a sensitivity analysis of labour cost and found that decreasing deconstruction labour cost by about 20% makes the deconstruction cost equal the demolition cost. Thus, household labour input into the building construction industries were increased by 20% for AR construction.

Changes to the observed construction “recipe” are summarized in Table 4.3. Sample calculations are shown in Appendix E.

**Table 4.3 – Existing and new  $u_{ij}$  reflecting adaptive reuse**

<b>Commodities</b>	<b>Non-residential, <math>\beta = 0.2</math></b>			<b>Residential, <math>\beta = 0.2</math></b>	
	<b>Change (%)</b>	<b>Existing (\$1000)</b>	<b>Basic (\$1000)</b>	<b>Existing (\$1000)</b>	<b>Basic (\$1000)</b>
Cement	-80.86	7588	6361	44302	37137
Ready-mixed concrete	-80.86	322260	270144	553836	464270
Concrete products	-80.86	191660	160665	189611	158947
Prefabricated metal buildings and components	-78.61	135421	114130	74692	62949
Fabricated steel plates and other fabricated structural metal	-78.61	213040	179546	235079	198120
Other architectural metal products	-78.61	120178	101284	422599	356158
Truck transportation services for general freight	-20	24441	23463	133386	128051
Truck transportation services for specialized freight	-20	58703	56355	302365	290270
Architectural, engineering and related services	+20	1112488	1156988	1044609	1086393
Household labour	+20	4740841	4930474	9212507	9581007

#### **4.1.2 Fixed Demand for adaptively reused buildings – 10%, 45%, 90% scenarios**

Scenarios ‘10%’, ‘45%’, and ‘90%’ build on the ‘Basic’ scenario where non-structural components of buildings are incorporated into the commodity recipe change. For example, furniture, windows, doors, wiring, interior finishes, plumbing, HVAC etc., are included. The commodity classifications were examined and the commodities that are deemed as non-structural components of buildings were selected for recipe change.

The changes in value for these commodities were estimated through a compilation of literature on AR/ deconstruction of buildings. In his case study of an outdoor activity retail store, Gorgolewski (2017) found that the building used 56% recycled or reused building materials by weight. In developing their cost

prediction model for building deconstruction, Tatiya et al., (2017) found that at least 42% of building materials were recoverable for reuse and recycling. Santos and Brito (2007) found that only 10% of materials were reused from a building deconstruction project in Portugal. In their case study of a 200 square foot residential building, Kibert and Languell (2000) found that reused building materials accounted for 30% by volume and 23% by weight. Saleh and Chini (n.d.) propose an additional credit to the material and resource category of LEED to account for design for AR. This proposed credit, MR Credit 9.3, recommends that at least 50% of the non-structural components be retained. Lastly, in their literature review, Pun, Liu, and Langston (2006) found that more than 90% of building materials are reusable. Table 4.4 below lists the commodities that are candidates for recipe change.

**Table 4.4 – Commodities to adjust for adaptive reuse recipe change**

<b>Commodities</b>
Textile products, n.e.c.
Hardwood lumber
Softwood lumber
Other sawmill products and treated wood products
Veneer and plywood
Wood trusses and engineered wood members
Reconstituted wood products
Wood windows and doors
Prefabricated wood and manufactured (mobile) buildings and components
Wood products, n.e.c.
Plastic and foam building and construction materials
Plastic products, n.e.c.
Rubber products, n.e.c.
Clay and ceramic products and refractories
Glass (including automotive), glass products and glass containers
Lime and gypsum products
Non-metallic mineral products, n.e.c.
Iron and steel basic shapes and ferro-alloy products
Iron and steel pipes and tubes (except castings)
Wire and other rolled and drawn steel products
Forged and stamped metal products
Metal windows and doors
Boilers, tanks and heavy gauge metal containers
Springs and wire products
Threaded metal fasteners and other turned metal products including automotive
Metal valves and pipe fittings
Fabricated metal products, n.e.c.
Heating and cooling equipment (except household refrigerators and freezers)
Other electronic components
Electric light bulbs and tubes
Lighting fixtures
Small electric appliances
Major appliances
Switchgear, switchboards, relays and industrial control apparatus
Wood kitchen cabinets and counter tops
Wholesale margins - building materials and supplies
Retail margins - furniture and home furnishings
Retail margins - building materials, garden equipment and supplies

Percent changes to these commodities were all assumed to be the same for simplicity. Utilizing findings in literatures mentioned above, percent changes were categorized in three scenarios; pessimistic, modest, and optimistic, where, 10%, 45%, and 90% changes to commodities recipes were applied, respectively. Tables (similar to Table 4.4) showing the recipe changes for scenarios ‘Basic’, ‘10%’, ‘45%’, and ‘90%’ are shown in Appendix F.

### 4.1.3 Scenarios for demand increase for adaptive reuse buildings

The second set of scenarios builds on the first set of scenarios (‘Basic’, ‘10%’, ‘45%’, and ‘90%’) where the final demand adaptively reused buildings increase. For each of the scenarios from the first set of scenarios (‘Basic’, ‘10%’, ‘45%’, and ‘90%’), the final demand of adaptively reused buildings was increased. Final demand increases of 2.5%, 5%, and 10%, in combination with the first set of four scenarios, creates 12 additional scenarios. Table 4.5 shows the existing and new final demand values for residential and non-residential building construction industries. Recall that the identifications for these scenarios are summarized in Table 4.1.

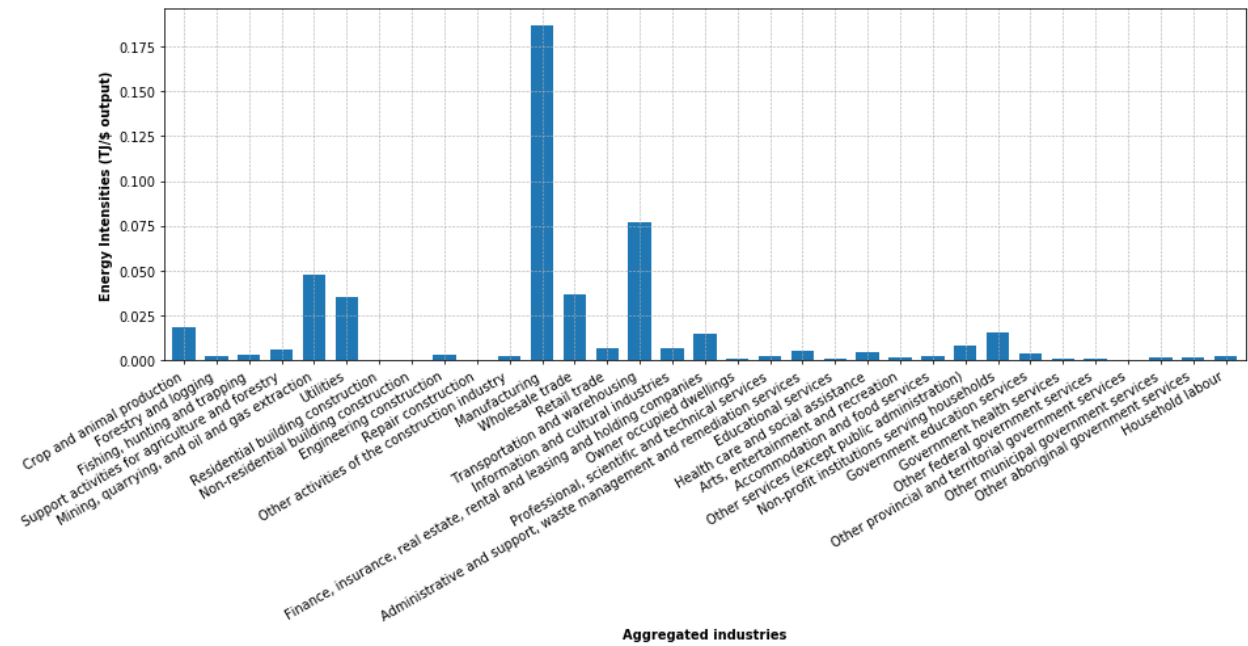
**Table 4.5 – Final demand changes for adaptive reuse of building industries**

<b>Residential building construction final demand, <math>\beta = 0.2</math></b>				
	<b>Existing and Base (\$1000)</b>	<b>2.5% final demand increase of AR buildings (\$1000)</b>	<b>5% final demand increase of AR buildings (\$1000)</b>	<b>10% final demand increase of AR buildings (\$1000)</b>
Residential building construction industry	\$36,936,512	\$37,121,194	\$37,305,877	\$37,675,242
<b>Non-residential building construction final demand, <math>\beta = 0.2</math></b>				
	<b>Existing and Base (\$1000)</b>	<b>2.5% final demand increase of AR buildings (\$1000)</b>	<b>5% final demand increase of AR buildings (\$1000)</b>	<b>10% final demand increase of AR buildings (\$1000)</b>
Non-residential building construction industry	\$15,009,509	\$15,084,556	\$15,159,604	\$15,309,699

## 4.2 Energy use and job intensities

Recall from Chapters 3.8 and 3.9 that energy use and jobs by industry were calculated using intensities, where energy use intensities are used to convert output changes into energy changes, and job intensities are used to find job changes. Figure 4.1 illustrates the energy intensities used in calculating energy use changes in Ontario

and RoW. Recall that energy intensities were determined using Canadian energy use by sector, and that Ontario and RoW assumed to have the same energy use intensities. Figure 4.1 shows that manufacturing is substantially more energy intensive than other industries in the economy. Other industries with notably high energy intensities are wholesale trade, transportation and warehousing, mining, utilities, and crop and animal productions. Thus, changing outputs for these industries will have a large influence over total energy use of an economy.



**Figure 4.1 – Energy intensities by aggregated industries**

Figure 4.2 shows the job intensities by aggregated industries. Note that the aggregation of industries is different than that of energy intensities. Job intensities are aggregated to 17 industries, compared to 33 industries for energy intensities, because Statistics Canada records employment data by 16 aggregated industries (to which households were added). Finance, manufacturing, utilities, and forestry, fishing, mining, quarrying, oil and gas, industries have relatively low job intensities compared to other industries.

Figure 4.2 shows that changing outputs of agriculture, construction, wholesale and retail, transportation and warehousing, education, health and social care, accommodation and food, and service industries will greatly affect total employment in an economy.

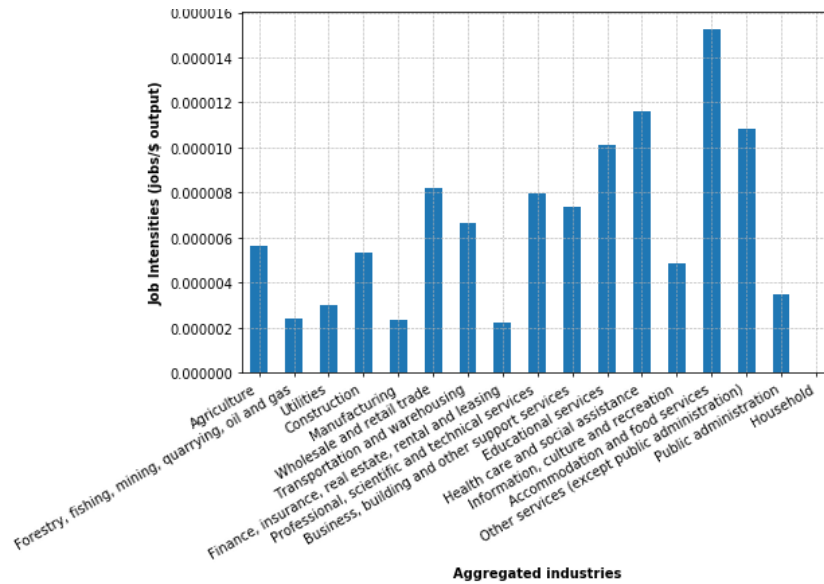


Figure 4.2 – Job intensities by aggregated industries

### 4.3 Results for adaptive reuse scenarios – Ontario

#### 4.3.1 Economic profile of Ontario

Hypothetical extractions/linkages, energy use, and intermediate input breakdowns were conducted in order to better understand the role and importance of the residential and non-residential construction industries within Ontario’s economy.

##### 4.3.1.1 Hypothetical extraction of building industries

Recall that hypothetical extraction is a method to measure an industry’s importance or total linkage to the economy. An industry’s total linkage (direct, indirect, and induced effects) is determined by ‘removing’ the industry from the economy and calculating the resulting decrease in value of gross output. Figure 4.3 shows the top 20 total economic activities measured in output in terms of percentage for Ontario. Residential and non-residential building construction industries (highlighted in red) are among the top 20 total economic activities out of 226 industries. This indicates that the building industries play a substantial role in Ontario’s economy. However, residential building construction has a more prominent presence compared to non-residential building construction. Total economic activity for residential building construction is approximately doubled of non-residential building construction.

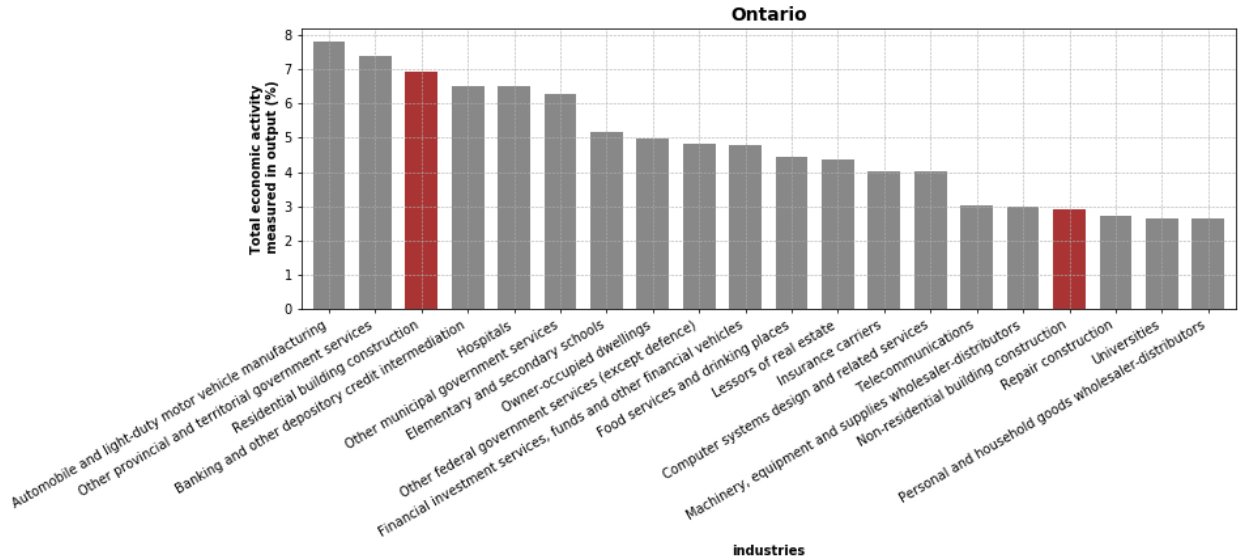


Figure 4.3 – Total economic activity in dollars for Ontario

Total economic activities can be measured in energy simply by converting the gross output by industry to energy use by industry as shown in Chapter 3.8. Figure 4.4 illustrate top 30 total economic activities measured in energy (terajoules TJ) in terms of percentage for Ontario. Residential and non-residential building construction industries (highlighted in red) are among the top 30 total economic activities out of 226 industries. Residential building construction is still among the top five, while non-residential building construction has dropped in rankings slightly. Nonetheless, the building industries still have a substantial role in the economy in terms of total economic activity measured by energy consumption.

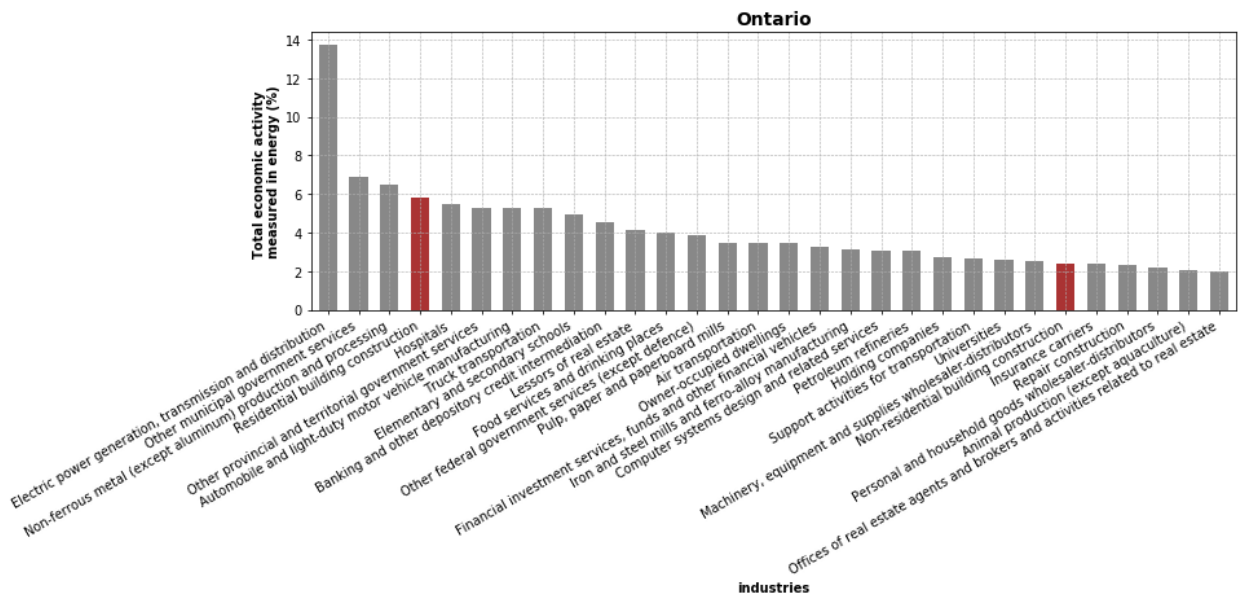


Figure 4.4 – Total economic activity measured in energy for Ontario



Table 4.6 summarizes the total economic activities in dollars and energy for the building industries of Ontario. Recall that  $T_j$ , and  $T_j^{energy}$  are total economic activity measured in output, and energy, respectively. The bar over the variable indicates total economic activity measured in percentage.

**Table 4.6 – Summary of hypothetical extraction for building industries in Ontario**

Region	Residential building construction				Non-residential building construction			
	$\bar{T}_j$ (%)	$T_j$ (\$1000)	$\bar{T}_j^{energy}$ (%)	$T_j^{energy}$ (TJ)	$\bar{T}_j$ (%)	$T_j$ (\$1000)	$\bar{T}_j^{energy}$ (%)	$T_j^{energy}$ (TJ)
Ontario	6.56	107,902,546	6.56	162320	2.83	46,526,397	2.26	68460

Again, total economic activity measures the total linkage (direct, indirect, and induced effects) of an industry by hypothetically removing an industry from an economy. One method to determine total economic activity is by hypothetical extraction. Hypothetical extraction of the building industries shows that residential building construction has a more important role in the economy than non-residential building construction. With the importance of the building industries within total economic activity determined, linkages were calculated to understand the effects the building industries has on other industries.

#### 4.3.1.2 Backward and forward linkages of building industries

Backward linkages for the building industries were calculated for Ontario. Table 4.7 summarizes the top 20 backward linkages for each building industry in Ontario. Recall that backward linkage is a measurement of economic pull of an industry or in other words, the strength of industry  $j$ 's dependence on interindustry inputs to produce industry  $j$ 's output

**Table 4.7 – Ontario’s top 20 backward linkages for each building industry**

Ontario				
Non-residential building construction			Residential building construction	
Rank	Top 20 Industries	Backward linkage (%)	Top 20 Industries	Backward linkage (%)
1	Household	78.98	Household	70.86
2	Owner-occupied dwellings	12.85	Owner-occupied dwellings	11.53
3	Banking and other depository credit intermediation	6.54	Banking and other depository credit intermediation	5.87
4	Lessors of real estate	6.16	Lessors of real estate	5.73
5	Architectural, engineering and related services	5.45	Building material and supplies wholesaler-distributors	3.80
6	Food services and drinking places	4.08	Financial investment services, funds and other financial vehicles	3.71
7	Cement and concrete product manufacturing	3.90	Food services and drinking places	3.70
8	Telecommunications	3.58	Insurance carriers	3.44
9	Financial investment services, funds and other financial vehicles	3.56	Telecommunications	3.28
10	Insurance carriers	3.45	Truck transportation	2.94
11	Architectural and structural metals manufacturing	2.82	Plastic product manufacturing	2.90
12	Building material and supplies wholesaler-distributors	2.57	Architectural and structural metals manufacturing	2.71
13	Automobile and light-duty motor vehicle manufacturing	2.55	Petroleum refineries	2.64
14	Petroleum refineries	2.51	Cement and concrete product manufacturing	2.46
15	Truck transportation	2.23	Automobile and light-duty motor vehicle manufacturing	2.29
16	Electric power generation, transmission and distribution	2.20	Other wood product manufacturing	2.29
17	Repair construction	2.10	<i>Architectural, engineering and related services</i>	2.24
18	Plastic product manufacturing	1.96	<i>Building material and garden equipment and supplies dealers</i>	2.17
19	<i>Food and beverage stores</i>	1.90	<i>Electric power generation, transmission and distribution</i>	2.07
20	<i>Personal and household goods wholesaler-distributors</i>	1.63	<i>Repair construction</i>	1.95
<b>Total backward linkage</b>		<b>230.55</b>	<b>Total backward linkage</b>	<b>217.73</b>

The bolded-italicized industries in Table 4.7 are industries that are present in Ontario’s top 20 backward linkages, but are not in RoW’s top 20 backward linkages (discussed later in Table 4.12). The industries highlighted in red in Table 4.7 indicate industries that are common to both residential and non-residential

building construction in Ontario. There are 17 common industries within the top 20 backward linkages. This shows that residential and non-residential building construction sectors have similar economic pull on the economy. One difference between the two industries is that residential construction induces more demand on 'Other wood product manufacturing.' This may be the result of numerous single-family dwellings, which are primarily built with lumber in Ontario. Looking at Table 4.7 it is shown that architecture and engineering services is lower for residential building construction. This shows that residential building construction has a weaker pull on architectural and engineering services than Non-residential building construction. This may be the result from the fact that engineering design of residential buildings varies less than engineering design of non-residential buildings. The smaller variation in residential building design means that less monetary/time resources are spent on them. Residential and non-residential building construction have very high backward linkages on households. This suggests that the building industries have very strong dependence on households. This is expected as construction requires large amounts of manual labour. Interestingly, 'Food services and drinking places' are ranked high among the building industries' backward linkages. This may be because construction workers tend to purchase food and drinks in the vicinity of the construction site. The building industries have strong backward linkages to financial sectors and real estate sectors. This is reasonable as construction projects tend to be capital heavy, so they require loans and credits from the financial sector to finance projects. Also, the building industries depend on the real estate industry to find tenants, so that landowners/developers can recover costs. Total backward linkages for both residential and non-residential building construction industries are greater than 100 percent. This indicates that the building industries have strong backward linkages to Ontario's economy and corroborates Giang and Pheng (2011) literature review on the construction industry's role in the economy.

Forward linkages for the building industries were calculated to be zero for all industries. This is because elements in the rows for the building industries in the regional input coefficient matrix are all zeroes. Recall that calculating forward linkages require changing the rows of interest to zeroes. Thus, with the building industries' rows already being zeroes, the resulting forward linkage calculations will result in zeroes. The building industries having all zeros for their rows in the regional input coefficient matrix means that they do not sell their outputs to other industries. Instead, the building industries only sell their outputs to final demand (i.e., consumers).

#### **4.3.1.3 Backward and forward linkages of households**

Adaptive reuse of buildings requires increased household labour input into residential and non-residential buildings. Thus, backward and forward linkages for households were examined to further understand its role in Ontario's economy. Table 4.8 below outlines the top 20 backward and forward linkages for households in Ontario. Recall that forward linkage measures the dependencies of other industries as buyers of industry  $j$ 's

outputs. Also, recall that backward linkages measure the strength of industry  $j$ 's dependence on interindustry inputs to produce industry  $j$ 's output. From another perspective, backward linkages measure an industry's 'pull' on an economy, while forward linkages measure an industry's 'push' on an economy.

**Table 4.8 – Ontario backward and forward linkages of households**

Ontario				
Household			Household	
Rank	Top 20 Industries	Backward linkage (%)	Top 20 Industries	Forward linkage (%)
1	Household	31.37	Household	31.37
2	Owner-occupied dwellings	16.27	Hospitals	5.38
3	Lessors of real estate	6.78	Banking and other depository credit intermediation	5.09
4	Banking and other depository credit intermediation	6.24	Other municipal government services	4.99
5	Food services and drinking places	4.79	Elementary and secondary schools	4.96
6	Telecommunications	3.93	Other provincial and territorial government services	4.82
7	Financial investment services, funds and other financial vehicles	3.69	Residential building construction	4.72
8	Automobile and light-duty motor vehicle manufacturing	3.22	Financial investment services, funds and other financial vehicles	4.09
9	Insurance carriers	3.19	Other federal government services (except defence)	3.97
10	Food and beverage stores	2.28	Computer systems design and related services	3.58
11	Petroleum refineries	2.25	Food services and drinking places	3.21
12	Repair construction	2.17	Automobile and light-duty motor vehicle manufacturing	3.13
13	Electric power generation, transmission and distribution	2.11	Insurance carriers	2.57
14	Meat product manufacturing	1.54	Repair construction	2.43
15	<b><i>Other municipal government services</i></b>	1.53	Machinery, equipment and supplies wholesaler-distributors	2.31
16	Clothing and clothing accessories stores	1.52	Universities	2.16
17	General merchandise stores	1.48	Non-residential building construction	2.14
18	Personal and household goods wholesaler-distributors	1.46	Lessors of real estate	2.12
19	<b><i>Offices of dentists</i></b>	1.45	Truck transportation	1.85
20	Universities	1.35	Personal and household goods wholesaler-distributors	1.78
<b>Total backward linkage</b>		<b>152.24</b>	<b>Total forward linkage</b>	<b>184.48</b>

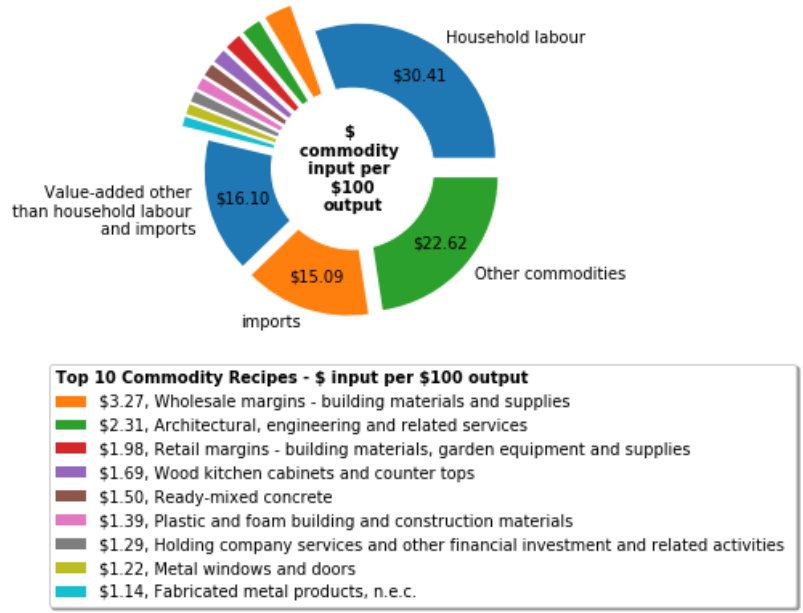
The bolded-italicized industries are industries that are present in Ontario's top 20 backward and forward linkages of households, but are not in RoW's households' top 20 backward and forward linkages (discussed

later in Table 4.13). The households' top backward and forward linkages are to itself. Recall that household row represents household labour that is used as input and household column represents households' consumption of input  $i$ . The strong backward linkage of households to themselves means that household consumption is dependent on household labour. The strong forward linkage of households to themselves means that household labour is very dependent on household consumption. In other words, a household consumes more of industry  $j$ 's output when more income is received through labour. However, the amount of income that household receives is dependent on how much households consume, since an increase consumption of industry  $j$ 's output requires increase in labour to produce more output. In essence, this is the circular flow of money.

Backward linkages of households are intuitive: households depend on the financial, food, energy (electric, oil, etc.), and communication sectors. On the other hand, forward linkages show that health, education, housing, and government sectors are primary purchasers of household labour. The implication of households' backward and forward linkages is explained with the following example. If households increase output, then backward linkages indicate that households will 'pull' more outputs from financial, food, energy, and communication sectors. In addition, forward linkages indicate that the increase in household output will 'push' health, education, housing, and government sectors to produce more output. Total backward and forward linkages for households in Ontario are both greater than 100%. This indicates that households are very important Ontario's economy.

#### 4.3.1.4 Breakdown of intermediate inputs of building industries

The Ontario Use matrix can be analyzed to see the existing commodity recipe for the building construction industries; more specifically, the  $\mathbf{B}$  matrix (recall from section 3.2.1 that the  $\mathbf{B}$  matrix is an equivalent to the ordinary technical coefficient matrix,  $\mathbf{A}$ ). Also, recall that Column  $j$  of the  $\mathbf{B}$  matrix represents the value of inputs of each commodity per dollar's worth of industry  $j$ 's output. Figure 4.5 illustrates the commodity recipe for residential building construction. Figure 4.5 is broken into five categories: household labour, other value-added, imports, other commodity inputs, and top 10 commodity inputs. From Figure 4.5, it is shown that value added alone (household labour, other value-added, and imports) constitutes about 62% of Ontario's residential building construction industry's inputs. On the other hand, the remaining 38% percent of the industry's input are commodities, where 10 commodities alone account for approximately 16% of all inputs.



**Figure 4.5 – Ontario residential building construction commodity recipe**

Figure 4.6 illustrates the commodity recipe for non-residential building construction. Like residential building construction, non-residential building construction was broken down into five segments. Figure 4.6 shows that value-added (household labour, other value-added, and imports) accounts for approximately 64% of commodity inputs into Ontario’s non-residential building construction industry inputs. The remaining 36% of the industry’s inputs are commodities, where 10 commodities alone account for approximately 16% of all inputs. Comparing Figure 4.5 and Figure 4.6, non-residential building construction uses substantially more architecture and engineering services (approx. 6.1%) than residential building construction does (2.3%). This implies that architects and engineers spend more time on designing non-residential than residential buildings if their services are billed equally regardless of building type. Also, the top 10 commodity recipes show that concrete and steel are more prevalent in non-residential buildings than in residential buildings.

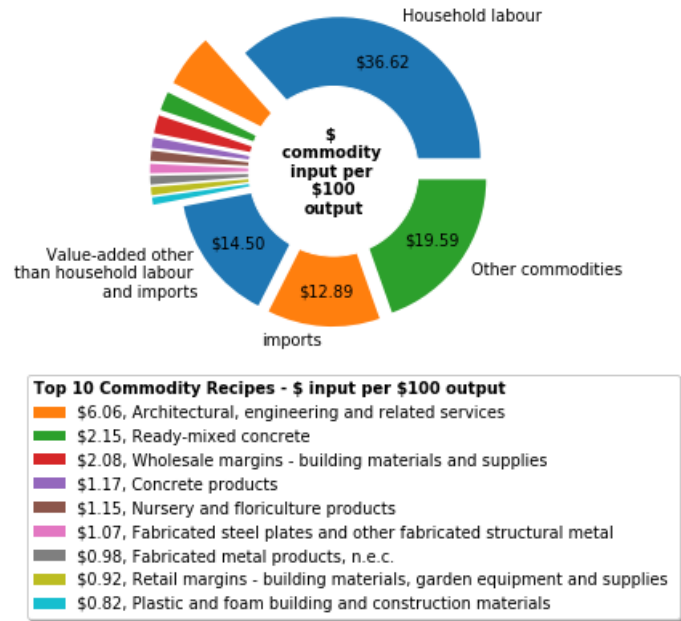


Figure 4.6 – Ontario non-residential building construction commodity recipe

### 4.3.2 Adjusting market share percentage

The effects of market share of adaptively reusable buildings on Ontario’s total output were studied by varying the market share percentage in the basic scenario. That is,  $\beta$  was varied from 20%, 40%, 60%, and 80%, while non-structural components were fixed at 0%. Figure 4.7 summarizes the findings of market share effects on total output for Ontario. Market share of adaptively reusable buildings has a linear effect on the total output changes for Ontario. As market share increases, the effects on total output changes are magnified linearly. From the plot for residential building construction, total output changes increase proportionately to the proportion of market share. For example, 40% market share of adaptively reusable residential buildings has doubled the effect on total output change than 20% market share. 60% market share has tripled the effect on total output change than 20% etc. This effect is expected as the IO model is linear in nature. However, this may not be reflective of large changes in the real world, since economic systems are complex. Increasing market share of AR construction in the building industries may have non-linear effects. These non-linear effects are not captured in IO models, which are a limitation of IO models.

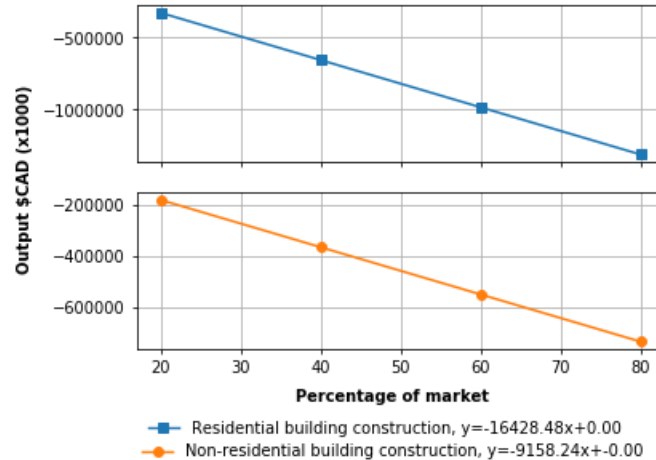


Figure 4.7 – Market share vs total output change for Ontario

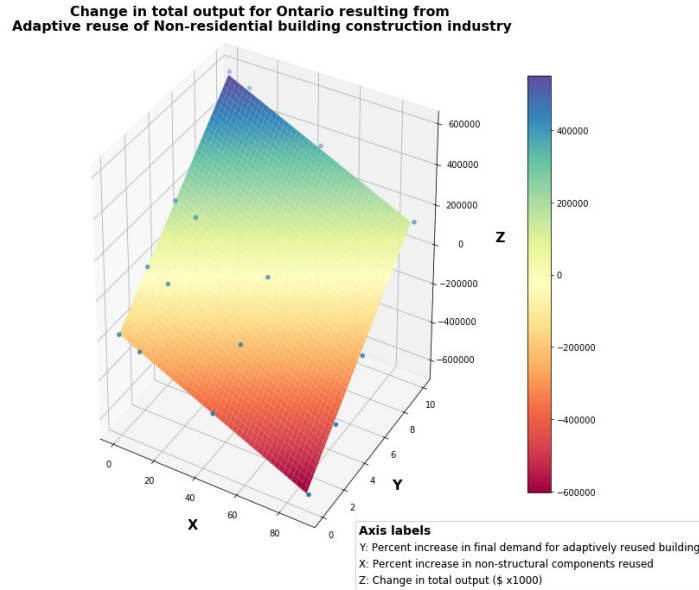
### 4.3.3 Adjusting percentage of non-structural components reused and demand increase

Market share of buildings capable of AR was held constant at 20% (i.e.,  $\beta = 0.2$ ), while percentage of non-structural components reused, and increase in final demand for adaptively reused buildings varied. Recall that percentage of non-structural components reused varied from 0%, 10%, 45%, and 90%, and increase in demand for adaptively reused buildings varies from 0%, 2.5%, 5% and 10%. Thus, a total of 16 scenarios were analyzed.

#### 4.3.3.1 GDP, total output, total job, and total energy use changes

Four measures of effectiveness were analyzed: GDP change, total output change, total job change, and total energy use. The four measures of effectiveness were determined for the 16 scenarios (Table 4.1) for each region for AR of each building industry. The results were plotted on a 3D scatter plot and a 3D plane was fitted: A total of 8 3D plots for Ontario were developed (4 measures of effectiveness multiplied by 2 industries). Figure 4.8 shows the 3D plot for total output change for AR of non-residential buildings in Ontario as an example. The remaining 3D plots are placed in Appendix G.





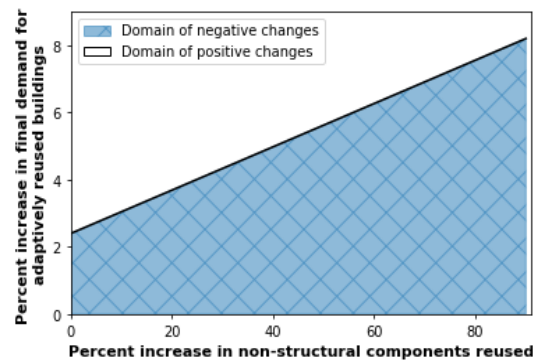
**Figure 4.8 – Example of 3D plot**

In general, all plots show the similar characteristics. Total output, jobs, and energy use decrease as the percentage of non-structural components reused increases. This is expected as material reuse enabled by AR reduces inputs into building construction. Also, total output, jobs, and energy use increase as the final demand of AR buildings increases. GDP increases as non-structural component reused and/or final demand increases. Recall that the Use table records industry uses of domestic and imported commodities. Thus, reducing the commodity recipe reduces imports, and hence GDP increases (since net exports increases). Also, increasing final demand for AR of residential or non-residential building increases GDP. The remaining 3D plots for change in GDP, total output, total jobs, total energy use for Ontario can be found in Appendix G.

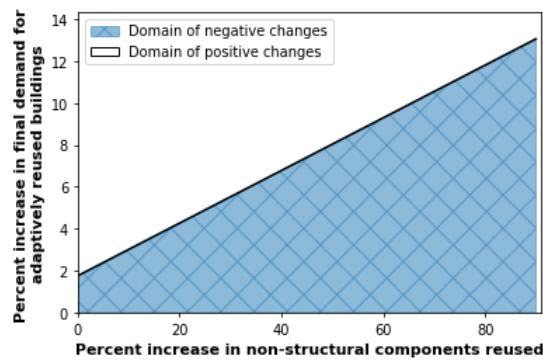
#### 4.3.3.2 Positive and negative domains

The contours of the 3D plots were examined to determine the domain of X (percent non-structural components reused), and Y (increase in final demand of adaptively reused buildings) that results in negative changes to GDP, output, jobs, and energy consumption. Figure 4.9 and Figure 4.10 shows domain plot for output changes for AR of non-residential and residential buildings in Ontario. The hatched area represents the domain of X and Y that results in negative changes to total output and the white space represents the domain of X and Y that results in positive changes to total output. In other words, combinations of X and Y are undesirable for output changes if they are within the hatched area and are desirable otherwise. The domain plot for output change is trapezoidal. This indicates that increase in final demand of AR buildings is necessary to produce positive total output change. At minimum, the final demand increase of AR buildings are required to increase approximately 2% to result in positive total output changes. As percent of non-

structural component reused increases, the final demand must increase to result in positive change of total output.



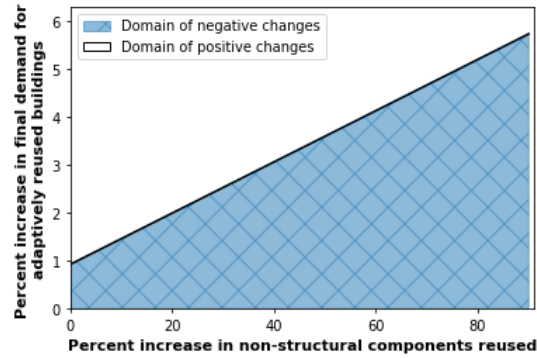
**Figure 4.9 – Domain of negative and positive changes in total output for Ontario resulting from adaptive reuse of non-residential building industry**



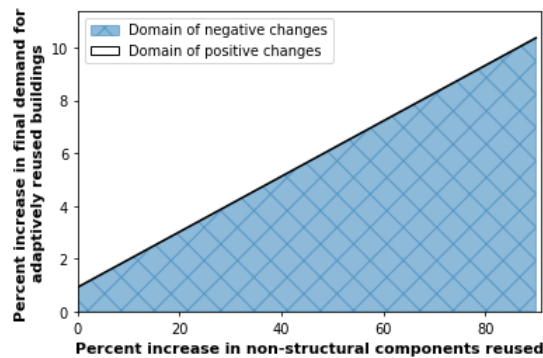
**Figure 4.10 – Domain of negative and positive changes in total output for Ontario resulting from adaptive reuse of residential building industry**

GDP change is the only domain plot that does not have a negative domain. Domain plots of GDP change for AR of non-residential or residential building are entirely empty, indicating that there is no combination of X and Y within the positive domain that results in a negative GDP change. This is also evident in the 3D planes for GDP changes, as the entire plane contains positive values.

Figure 4.11 and Figure 4.12 shows the domain plot for job changes for AR of non-residential and residential buildings in Ontario. The domains of job losses are also trapezoidal. Unlike total output change, the required final demand increases in AR buildings to result in positive job changes are lower. For example, at X = 0, 1% increase in final demand for AR is required for positive job change compared to 2% required for positive total output change. In other words, the domains of job losses are within the domains of negative total output change. This is shown later in Figure 4.15 and Figure 4.16.

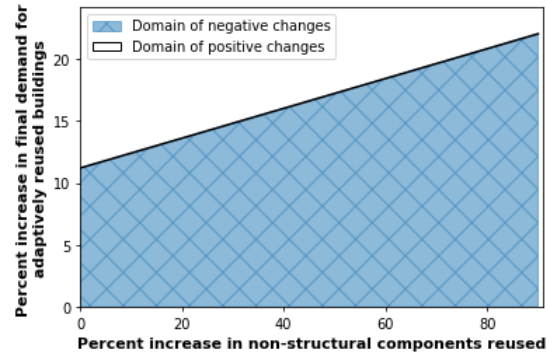


**Figure 4.11 – Domain of negative and positive changes in jobs in Ontario resulting from adaptive reuse of non-residential building industry**

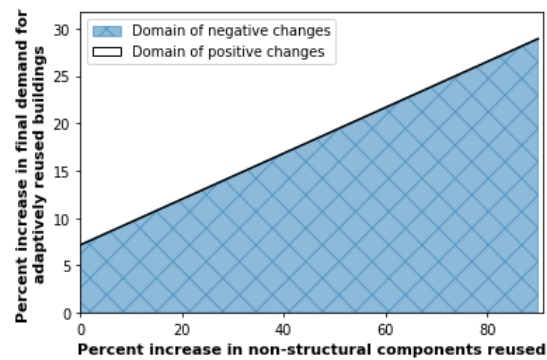


**Figure 4.12 – Domain of negative and positive changes in jobs in Ontario resulting from adaptive reuse of residential building industry**

Figure 4.13 and Figure 4.14 show domain plots for energy use changes for AR of non-residential and residential buildings in Ontario. Domain plots for energy use are opposite to the domain plots for GDP, jobs, and outputs. A negative change in energy consumption is seen as a positive effect, since less energy is consumed. Thus, the hatched area in the energy use domain plot shows the desirable combinations of X and Y, while the white spaces shows the undesirable combinations of X and Y. Energy domain plots for the building industries are trapezoidal. This indicates that AR of buildings reduces energy consumption up until a certain percent increase in final demand of AR buildings. The boundary between positive and negative change of energy use is higher than the boundaries in total output and job change. In other words, the domain of negative changes for total output and job change are within the domain of negative energy use. This is shown later in Figure 4.15 and Figure 4.16.



**Figure 4.13 –Domain of negative and positive changes in total energy use in Ontario resulting from adaptive reuse of non-residential building industry**



**Figure 4.14 –Domain of negative and positive changes in total energy use in Ontario resulting from adaptive reuse of residential building industry**

Each domain plots (output, GDP, job, energy use) shows generally show similar characteristic, i.e., the upper bound constraint is bounded by a positive sloped line resulting in a trapezoidal domain. The only exception is GDP change, since GDP changes do not exhibit negative changes. Generally, the domains are larger for the scenarios where AR is applied to the residential building construction.

Domain plots of all four measures of effectiveness (output, GDP, jobs, energy) can be plotted together to determine the domain that is desirable to all four measures of effectiveness. Figure 4.15 and Figure 4.16 shows the desired domain for AR of the building industries. The desired domain is where change in energy use is negative, while change in GDP and jobs are positive. This domain lies in the area that is underneath the energy domain boundary, and above the domain boundaries of GDP, and jobs. Note that GDP domain boundary is not present in Figure 4.15 and Figure 4.16 because GDP changes are positive for positive domains of X and Y.

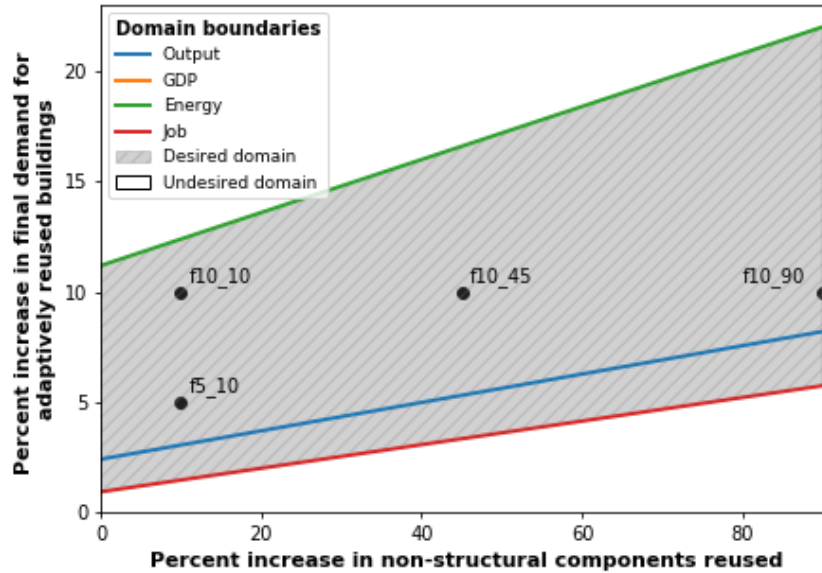


Figure 4.15 – Desired domain for adaptive reuse of non-residential building industry in Ontario

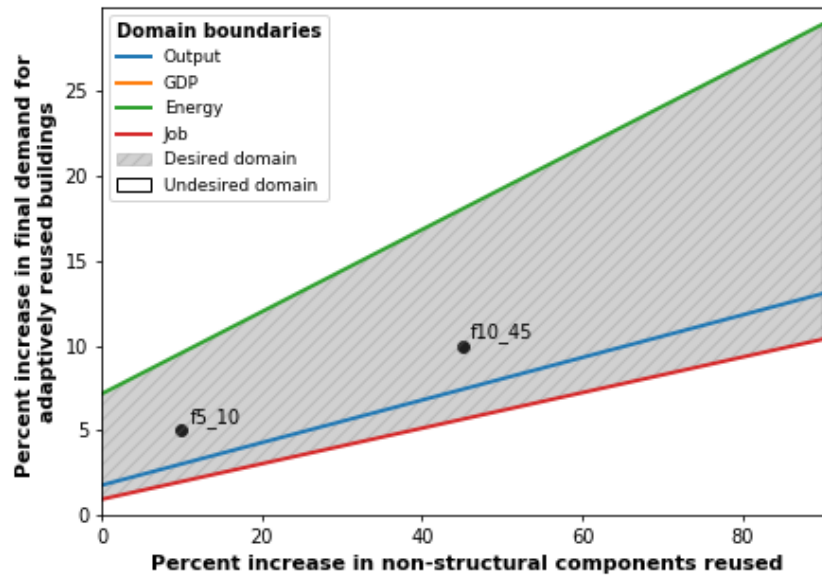


Figure 4.16 – Desired domain for adaptive reuse of residential building industry in Ontario

Scenarios ‘f5\_10’, ‘f10\_10’, ‘f5\_45’ and ‘f10\_90’ in Figure 4.15, and ‘f5\_10’, and ‘f10\_45’ in Figure 4.16 are scenarios where total output changes are positive, but energy use changes are negative. This may appear counter intuitive since energy use is linearly proportionate to output. Situations like these arise because of variations in industrial energy intensities. 90% of all negative output change consists of manufacturing, wholesale trade, mining, and transportation and warehousing, where energy intensities for these industries are 0.1866, 0.0371, 0.0476, and 0.077 TJ per \$ output, respectively. On the other hand, 90% of all positive output changes consist of professional and scientific services; Finance, insurance, real estate, rental and leasing,

holding companies; owner occupied dwellings; and non-residential or residential buildings, where their energy intensities are, 0.00273, 0.015, 0.00126, and 0.000142 or 0.000238 TJ per \$ output, respectively. Energy intensities of industries experiencing decrease in outputs are substantially larger than energy intensities of industries experiencing increases in output. Thus, certain compositions of negative and positive industry output changes results in scenarios where total output change is positive, but total energy use change is negative. In other words, the economy is shifting activity from energy-intense sectors, such as manufacturing, to sectors with lower energy consumption, such as professional and scientific services.

#### **4.3.3.3 Aggregate changes in output**

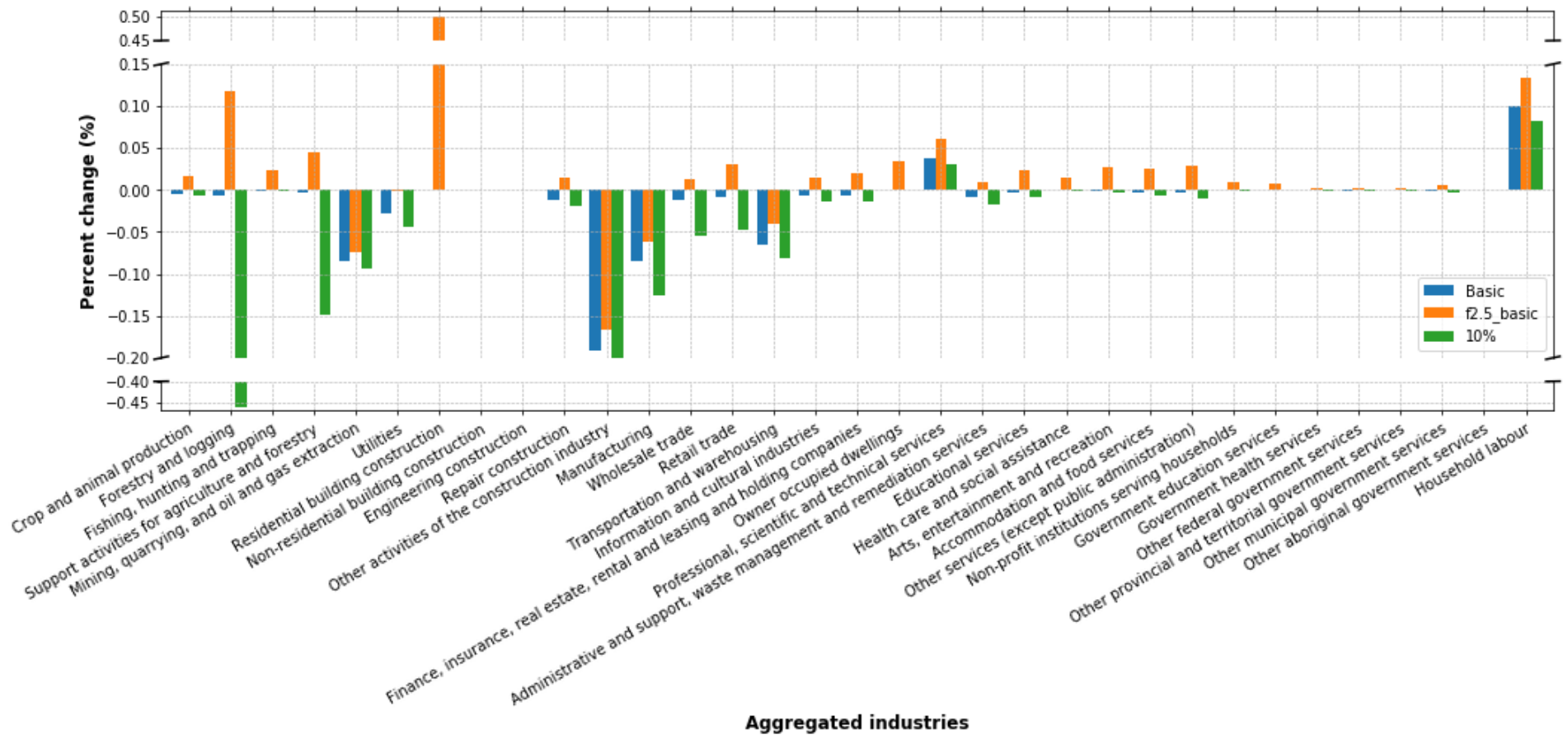
The output changes of AR of Ontario's building industries were examined further. First, the aggregated changes to output were examined to provide a high-level view of the effects of AR of buildings on industries. Recall that the concordance of summary level and detail level industry classifications are found in Table A2 in Appendix A. The detailed level industry output was aggregated to the summary level industry output and then plotted on a bar chart. Figure 4.17 shows the plots of aggregated changes to output of residential building construction for 'Basic,' '10%,' and 'f2.5\_basic' scenario for Ontario. The remaining aggregated plots for each scenario and building industry is illustrated in Appendix H.

The 'basic' scenario in Figure 4.17 illustrates large reductions construction activity, manufacturing, transportation and warehousing, and mining. These are indirect effects of reducing the concrete, steel, and transportation inputs into residential building construction, as well as other commodities outlined in Figure 4.17. Mining and utilities output also experiences reduced output as a consequent of indirect effect from reduction in concrete and steel manufacturing. Despite seeing a large increase in household labour, output changes of industries with strong linkages to household labour (induced effects of household labour) are generally small or negative for 'Basic', as well as '10%', '45%', and '90%' scenarios. The induced effects of household labour were expected to increase output industries related to health, education, food, and services. However, this is not the case for 'Basic', '10%', '45%', and '90%' scenarios of AR of residential and non-residential buildings. The small changes of household induced effects are a result of two factors. First, recall that household labour was changed for only one industry (residential, or non-residential building construction) out of 226 industries. Hence, the induced effects are expected to be small. Secondly, final demand is fixed for 'Basic', '10%', '45%', and '90%' scenarios. This means that there are no final demand changes to drive the output changes of industries with strong linkages to households. In general, the induced effects of household labour increase relative to the 'Basic' scenario as the final demand of residential or non-residential building construction increases. Furthermore, the induced effects of household labour decrease relative to the 'Basic' scenario as the percentage of non-structural component reuse increases. The other

notable positive output change from 'Basic' scenarios is 'Professional, scientific, and technical services.' This is the direct result of increasing architecture and engineering services.

Recall that the 'Basic' scenario reflects the AR of a building's super- and substructures and ignores reuse of internal non-structural components. The green bars in Figure 4.17 shows the aggregated changes to output resulting from AR of residential building industry for '10%' scenario for Ontario. The green bars in Figure 4.17 shows the general effect on output changes as percentage of non-structural component reused increases. The '10%' scenario shows one major difference compared to the 'Basic' scenario. This difference is the result of the vast decrease in output for the 'Forestry and logging' industry. Also, the 'Support activities for agriculture and forestry' industry decreases its output as an indirect effect. Reducing input of wood products in residential building construction is expected to have large impacts on the 'Forestry and logging' industry. This is evident from the economic pull that residential building construction has on the wood product manufacturing as shown in backward linkage measures in Table 4.7. Furthermore, the existing interindustry recipe has wood product manufacturing as its fourth most used input in producing residential buildings.

The orange bars in Figure 4.17 shows the aggregated output changes for 'f2.5\_basic' scenario for residential building construction for Ontario. The orange bars in Figure 4.17 are used to show the general effect on output changes as final demand of adaptively reused buildings increase. Recall that 'f2.5\_basic' takes the 'Basic' scenario and increases the final demand of AR buildings. Scenario 'f2.5\_basic' has three notable differences compared to the 'Basic' scenario. Firstly, output changes for residential building construction are non-zero. This results from directly changing final demand for residential building construction. Secondly, output of industries related to health, education, food, recreation, government and services have increased. The output increase in these industries stem from the endogenized household sector (i.e., increased household spending due to increased incomes). Thirdly, increasing final demand of AR residential buildings increases output of the forestry industries relative to 'Basic' scenario.



**Aggregated industries**

Figure 4.17 – Change in aggregated output resulting from adaptive reuse of residential building industry, ‘Basic,’ ‘10%,’ and ‘f2.5\_basic’ scenario for Ontario



Figure 4.18 shows the plots of aggregated changes to output of non-residential building construction for 'Basic,' '10%,' and 'f2.5\_basic' scenarios for Ontario. Figure 4.18 shows that AR of non-residential buildings has similar effects as its residential counterpart. However, the only difference is the magnitude. The reductions in outputs for the non-residential building scenarios are generally smaller than the residential building scenarios. This aligns with the results from hypothetical extraction in Figure 4.3, which depicts that non-residential building construction has a smaller total economic activity in comparison to residential building construction.

The green bars in Figure 4.18 shows the aggregated output changes for scenario '10%' for non-residential building construction for Ontario. The green bars in Figure 4.18 shows the general effect on output changes as percentage of non-structural component reused increases. The green bars in Figure 4.18 shows that AR of non-residential building with 10% non-structural component reuse also experiences a noticeable decrease in 'Forestry and logging' output in comparison to its 'Basic' scenario counterpart. However, this decrease in output is relatively smaller compared to '10%' scenario for residential buildings, as shown with green bars in Figure 4.17. This is because non-residential building construction has a weaker economic pull on wood products, as depicted in Table 4.7 and Figure 4.6.

The orange bars in Figure 4.18 show the aggregated output changes for 'f2.5\_basic' scenario for non-residential building construction for Ontario. The orange bars in Figure 4.18 shows the general effect on output changes as demand of adaptively reused buildings increase. The orange bars in Figure 4.18 show that 'f2.5\_basic' scenario has three notable difference compared to 'Basic' scenario for AR of non-residential buildings. Firstly, output change for non-residential building construction is non-zero. Secondly, output of industries related to health, education, food, recreation, government, and services have increased. Thirdly, increasing final demand of AR of non-residential buildings increases output of the forestry industries relative to 'Basic' scenario. However, the changes in the forestry industries are not as large as the residential equivalent.

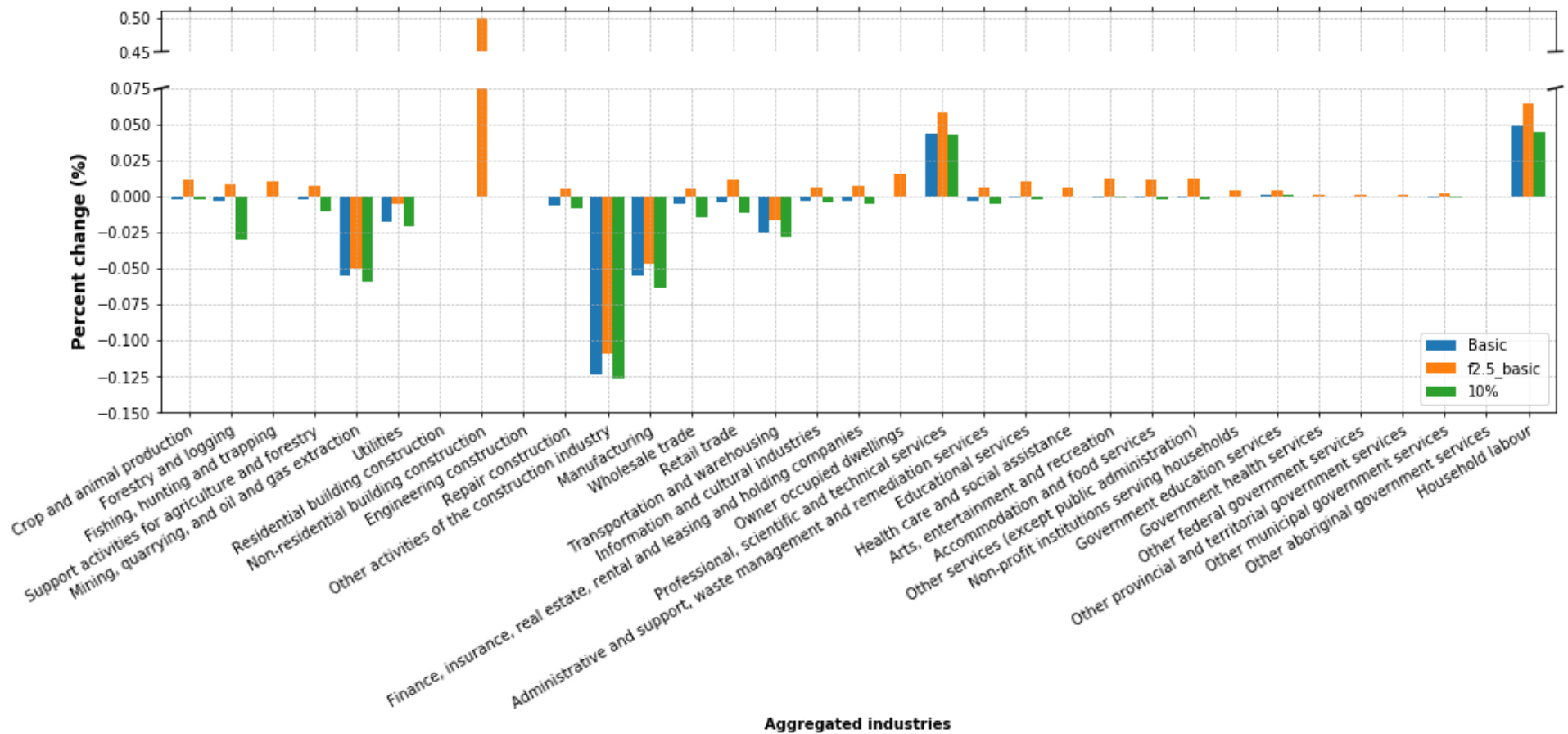


Figure 4.18 – Change in aggregated output resulting from adaptive reuse of non-residential building industry, ‘Basic,’ ‘10%,’ and ‘f2.5\_basic’ scenario for Ontario

#### **4.3.3.4 Top 10 increases and decreases in industry output**

Aggregated data are suitable for providing a high-level view of the effects of AR of buildings on industry output. However, the aggregated data mask detailed information of industries. For example, although the aggregated plots show a decrease in overall manufacturing output, there may be certain manufacturing industries that experience increases in outputs. Although there are 226 industries, results for all 226 industries are not presented. Recall that a substantial portion of residential and non-residential building inputs is accounted for by 10 industries, as shown previously in Figure 4.5 and Figure 4.6. Thus, the top 10 increases and decreases in industry output were examined for each scenario and summarized in tables. Table 4.9 is an example table for Ontario.

Table 4.9 – Example of tables for top 10 increases and decreases in industry output

Ontario 'Basic' Scenario						
Top 10 decreases						
Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x \$1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.76	Cement and concrete product manufacturing	-91594.40	-2.47
2	Architectural and structural metals manufacturing	-	-1.30	Architectural and structural metals manufacturing	-45022.52	-0.91
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-5488.28	-1.07	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3599.30	-0.70
4	Stone mining and quarrying	-2807.90	-0.38	Stone mining and quarrying	-1842.25	-0.25
5	Forging and stamping	-3675.65	-0.36	Forging and stamping	-1950.57	-0.19
6	Cutlery, hand tools and other fabricated metal product manufacturing	-7226.64	-0.26	Boiler, tank and shipping container manufacturing	-1999.34	-0.13
7	Other activities of the construction industry	-2542.43	-0.19	Other activities of the construction industry	-1643.67	-0.12
8	Boiler, tank and shipping container manufacturing	-2914.55	-0.19	Non-metallic mineral product manufacturing (except cement and concrete products)	-3450.15	-0.12
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-5023.72	-0.17	Cutlery, hand tools and other fabricated metal product manufacturing	-3002.75	-0.11
10	Machine shops, turned product, and screw, nut and bolt manufacturing	-3895.53	-0.14	Alumina and aluminum production and processing	-1877.50	-0.09
Top 10 increases						
Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	27901.48	0.29	Architectural, engineering and related services	30152.24	0.31
2	Household	378011.75	0.10	Household	184656.96	0.05
3	Food, beverage and tobacco wholesaler-distributors	1608.41	0.01	Food, beverage and tobacco wholesaler-distributors	1901.27	0.02
4	Specialized design services	78.68	0.01	Specialized design services	127.12	0.01
5	Universities	546.16	0.00	Management, scientific and technical consulting services	412.42	0.01
6	Computer systems design and related services	478.66	0.00	Computer systems design and related services	1011.83	0.00
7	Management, scientific and technical consulting services	41.59	0.00	Universities	615.93	0.00
8	Medical equipment and supplies manufacturing	7.56	0.00	Other professional, scientific and technical services	206.71	0.00
9	Other professional, scientific and technical services	11.76	0.00	Data processing, hosting, and related services	67.35	0.00
10	Private households	0.00	0.00	Medical equipment and supplies manufacturing	39.82	0.00

The remaining tables for other scenarios are presented in Appendix I. Table 4.10 summarizes the findings of the top 10 increases and decreases in detailed industry output.

**Table 4.10 – Generalization of top 10 increases and decreases in industry output**

<b>Adaptive reuse of residential buildings</b>	
<b>Scenarios</b>	<b>Industries</b>
<b>Top 10 increases</b>	
<b>f2.5_basic, f5_basic, f10_basic</b>	sawmills and wood preservation, veneer, plywood and engineered wood products, household and institutional furniture and kitchen cabinet manufacturing, forestry and logging. Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing
<b>Basic, 10%, 45%, 90%</b>	typically, only engineering services, and household labour
<b>All other scenarios (f2.5_10, f2.5_45, f2.5_90, f5_10, f5_45, f5_90, f10_10, f10_45, and f10_90)</b>	funeral, gambling, gardening, dentists, public transit, private household employment, residential renting and leasing.
<b>Top 10 decreases</b>	
<b>All scenarios</b>	Concrete, and structural metal plus intermediate inputs such as iron and steel mills, and ferro alloy, stone, sand, gravel, clay mining, and non-metallic mineral product except cement and concrete. Building material and garden equipment. Aluminium manufacturing
<b>All scenarios except Basic, f2.5_Basic, f5_basic, f10_basic</b>	sawmills and wood preservation, veneer, plywood and engineered wood products, household and institutional furniture and kitchen cabinet manufacturing, forestry and logging.
<b>Adaptive reuse of non-residential buildings</b>	
<b>Scenarios</b>	<b>Industries</b>
<b>Top 10 increases</b>	
<b>Basic, 10, 45, 90</b>	engineer services, household, food
<b>All except Basic, 10, 45, 90</b>	Specialized design services, gardening, food
<b>all except Basic, f2.5_basic, f5_basic, f10_basic</b>	private households' employment
<b>Top 10 decreases</b>	
<b>All scenarios</b>	boiler, tank, and shipping container manufacturing. Sand, gravel, clay, ceramic, stone mining
<b>Most scenarios</b>	electric lighting, spring and wire manufacturing. Forging and stamping. Ventilation, air conditioning, commercial refrigeration equipment, machine shop, turned product, and screw, nut, and bolt manufacturing

In general, detailed industry output results are aligned with aggregated industry results. Industries that experience decrease in outputs are industries that provide products and services to residential and non-residential buildings. Industries that experience increases in output are industries that have strong linkages to households.

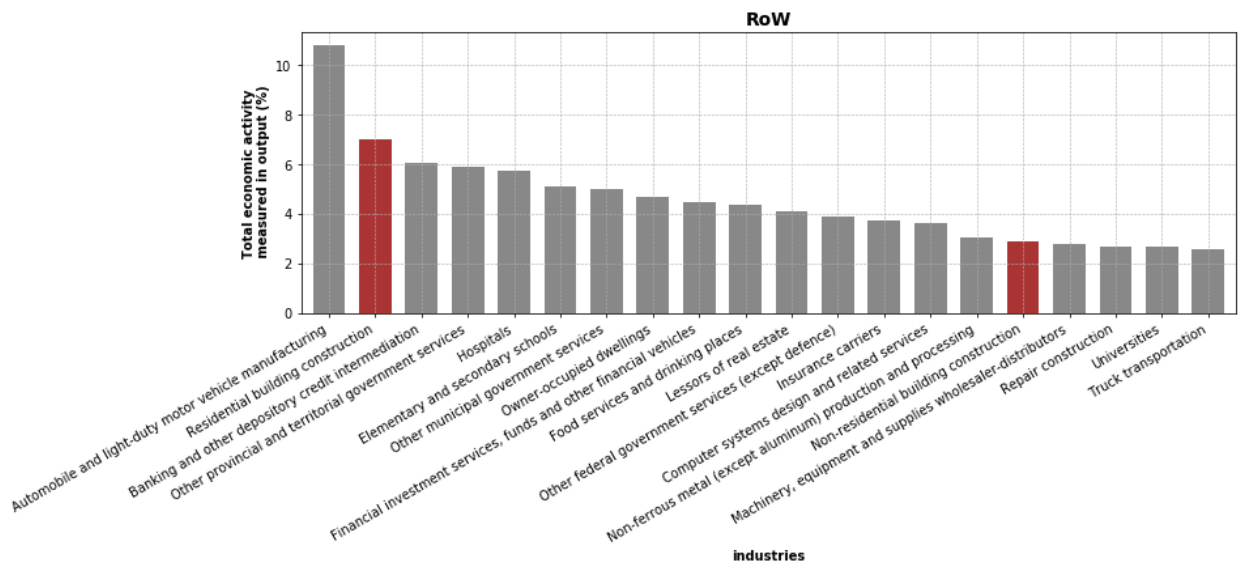
## 4.4 Results for adaptive reuse scenarios – Region of Waterloo

Hypothetical extractions/linkages, energy use, and intermediate input breakdowns were conducted in order to better understand the role and importance of the residential and non-residential construction industries within RoW's economy.

### 4.4.1 Economic profile of Region of Waterloo

#### 4.4.1.1 Hypothetical extraction of building industries

Figure 4.19 shows the top 20 total economic activities measured in dollars for RoW. Total economic activities for RoW are similar to Ontario despite RoW being a small portion of Ontario. Residential and non-residential building construction industries (highlighted in red) are among the top 20 total economic activities out of 226 industries. This indicates that the building industries also play a substantial role in RoW's economy. However, residential and non-residential building construction are ranked 2<sup>nd</sup> and 16<sup>th</sup> in RoW versus being ranked 3<sup>rd</sup> and 17<sup>th</sup> in Ontario.



**Figure 4.19 – Total economic activity in dollars for Region of Waterloo**

Total economic activities measured in energy for RoW are shown in Figure 4.20. Total economic activities in energy for RoW are like Ontario. One difference is that residential, and non-residential building construction are ranked 3<sup>rd</sup> and 22<sup>nd</sup> for RoW, but 4<sup>th</sup> and 24<sup>th</sup> for Ontario.

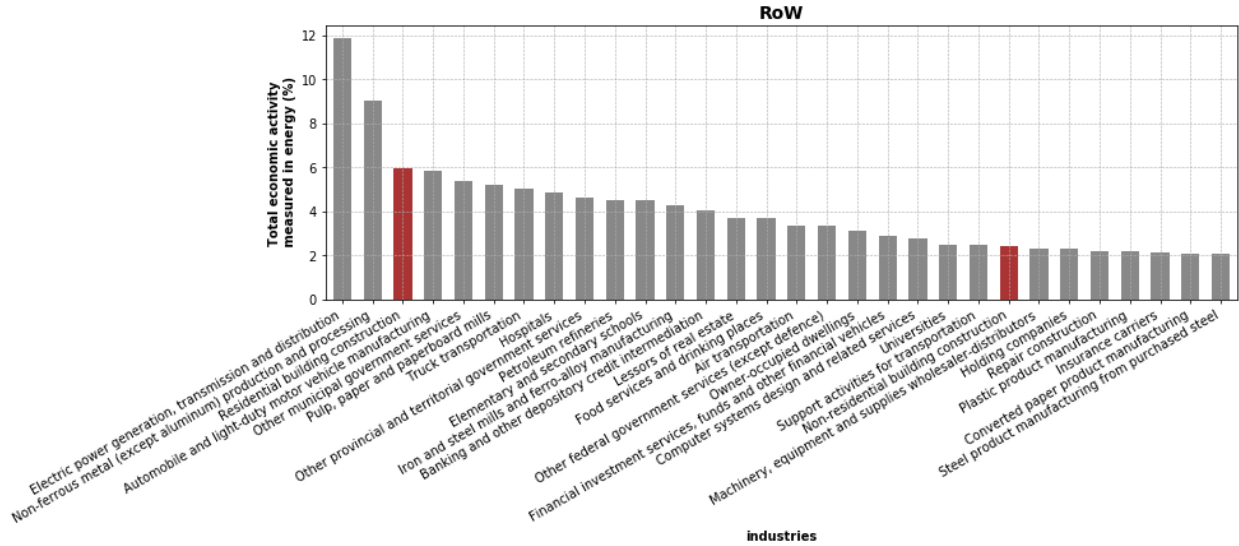


Figure 4.20 – Total economic activity in energy for Region of Waterloo

Table 4.11 summarizes total economic activities in dollars and energy for the building industries in RoW, as well as Ontario. Recall that  $T_j$ , and  $T_j^{energy}$  are total economic activity measured in output, and energy, respectively. The bar over the variable indicates total economic activity measured in percentage.

Table 4.11 – Summary of hypothetical extraction for building industries – RoW and Ontario

Region	Residential building construction				Non-residential building construction			
	$\bar{T}_j$ (%)	$T_j$ (\$1000)	$\bar{T}_j^{energy}$ (%)	$T_j^{energy}$ (TJ)	$\bar{T}_j$ (%)	$T_j$ (\$100)	$\bar{T}_j^{energy}$ (%)	$T_j^{energy}$ (TJ)
Ontario	6.56	107,902,546	6.56	162320	2.83	46,526,397	2.26	68460
Region of Waterloo	7.30	5,198,670	6.13	8507	3.07	2,190,358	2.50	3470

It is expected for the magnitude of total economic activity to be vastly different between Ontario and RoW. Hypothetical extraction of the building industries in RoW shows that total economic activities of RoW are approximately equal to Ontario in terms of percentage. With the importance of the building industries within total economic activity determined, linkages were calculated to understand the effects the building industries has on other industries.

#### 4.4.1.2 Backward and forward linkage of building industries

Backward linkages were calculated for Ontario. Table 4.12 summarizes the top 20 backward linkages for each building industry in Ontario. Recall that backward linkage is a measurement of economic pull of an industry or in other words, the strength of industry  $j$ 's dependence on interindustry inputs to produce industry  $j$ 's output.

**Table 4.12 – Region of Waterloo’s top 20 backward linkages for each building industry**

Region of Waterloo				
Non-residential building construction			Residential building construction	
Rank	Top 20 Industries	Backward linkage (%)	Top 20 Industries	Backward linkage (%)
1	Household	67.89	Household	60.91
2	Owner-occupied dwellings	12.23	Owner-occupied dwellings	10.97
3	Cement and concrete product manufacturing	6.81	Banking and other depository credit intermediation	5.54
4	Banking and other depository credit intermediation	6.17	Lessors of real estate	5.45
5	Lessors of real estate	5.85	Plastic product manufacturing	5.00
6	Architectural and structural metals manufacturing	4.81	Architectural and structural metals manufacturing	4.63
7	Architectural, engineering and related services	4.64	Petroleum refineries	4.45
8	Automobile and light-duty motor vehicle manufacturing	4.31	Cement and concrete product manufacturing	4.30
9	Petroleum refineries	4.24	Other wood product manufacturing	3.91
10	Food services and drinking places	3.89	Automobile and light-duty motor vehicle manufacturing	3.87
11	Plastic product manufacturing	3.39	Food services and drinking places	3.53
12	Insurance carriers	3.26	Building material and supplies wholesaler-distributors	3.39
13	Financial investment services, funds and other financial vehicles	3.25	Financial investment services, funds and other financial vehicles	3.39
14	Telecommunications	2.57	Insurance carriers	3.26
15	<b><i>Non-metallic mineral product manufacturing (except cement and concrete products)</i></b>	2.57	<b><i>Household and institutional furniture and kitchen cabinet manufacturing</i></b>	2.83
16	Building material and supplies wholesaler-distributors	2.29	Truck transportation	2.82
17	<b><i>Meat product manufacturing</i></b>	2.22	Telecommunications	2.35
18	Truck transportation	2.15	<b><i>Non-metallic mineral product manufacturing (except cement and concrete products)</i></b>	2.34
19	Repair construction	2.10	<b><i>Sawmills and wood preservation</i></b>	2.23
20	Electric power generation, transmission and distribution	1.99	<b><i>Meat product manufacturing</i></b>	1.99
<b>Total backward linkage</b>		<b>231.83</b>	<b>Total backward linkage</b>	<b>224.32</b>

The bolded-italicized industries are industries that are present in the top 20 backward linkages for RoW but are not in Ontario’s top 20 backward linkages (discussed in Table 4.7). The industries highlighted in red indicate industries that are common to both residential and non-residential building construction in RoW. There are 17 common industries within the top 20 backward linkages. This shows that residential and non-residential building construction sectors have similar economic pull effects on the economy. The notable differences between these two industries are that: residential construction induces more demand on wood



production/products. Total backward linkages for both residential and non-residential building construction industries are greater than 100 percent. This indicates that the building industries have high backward linkages to RoW's economy.

Backward linkages for non-residential building construction are similar between RoW and Ontario. There are 18 common industries within the top 20 backward linkages between RoW and Ontario. Backward linkages for residential building construction are not as similar between RoW and Ontario. There are 16 common industries in the top 20 backward linkages between RoW and Ontario. RoW has a stronger economic pull on 'other wood product manufacturing' with a backward linkage of 3.91% versus 2.29% in Ontario. Also, 'Household and institutional furniture and kitchen cabinet manufacturing,' and 'sawmills and wood preservation' is within the top 20 for RoW, but not in Ontario. Also, 'Non-metallic mineral product manufacturing (except cement and concrete products),' and 'meat product manufacturing' are present in the top 20 backward linkages for RoW for both industries, but not in Ontario. In RoW residential building construction's backward linkages for meat product, and non-metallic mineral product manufacturing are 2.34%, and 1.99%, respectively, compared to 1.14%, and 1.34% in Ontario. Also, ROW non-residential building construction's backward linkages for meat product, and non-metallic mineral product manufacturing are 2.57%, and 2.22%, respectively, compared to 1.27%, and 1.5% in Ontario.

Forward linkages for the building industries were calculated to be zero for all industries. This is because elements in the rows for the building industries in the regional input coefficient matrix are all zeroes. Recall that calculating forward linkages require changing the rows of interest to zeroes. Thus, with the building industries' rows already being zeroes, the resulting forward linkage calculations will result in zeroes. The building industries having all zeros for their rows in the regional input coefficient matrix means that they do not sell their outputs to other industries. Instead, the building industries only sell their outputs to final demand.

#### **4.4.1.3 Backward and forward linkages of households**

Adaptive reuse of buildings requires increase household labour input into residential and non-residential buildings. Thus, backward and forward linkages for households was examined to further understand its role in RoW's economy. Table 4.13 outlines the top 20 backward and forward linkages for households in Ontario. Recall that forward linkage measures the dependencies of other industries as buyers of industry  $j$ 's outputs. Also, recall that backward linkages measure the strength of industry  $j$ 's dependence on interindustry inputs to produce industry  $j$ 's output.

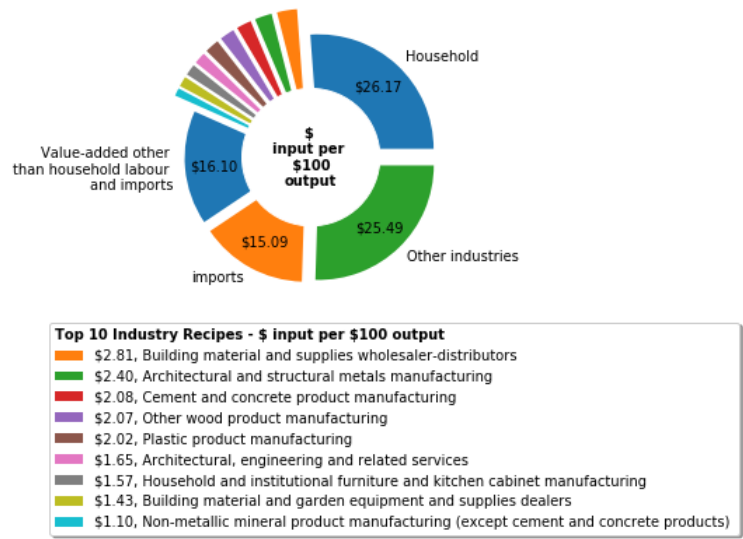
**Table 4.13 – Region of Waterloo’s backward and forward linkages of households**

Region of Waterloo				
Household		Household		
Rank	Top 20 Industries	Backward linkage (%)	Top 20 Industries	Forward linkage (%)
1	Household	31.22	Household	22.86
2	Owner-occupied dwellings	18.01	Banking and other depository credit intermediation	4.40
3	Lessors of real estate	7.48	Elementary and secondary schools	4.37
4	Banking and other depository credit intermediation	6.85	Hospitals	4.05
5	Automobile and light-duty motor vehicle manufacturing	6.32	Residential building construction	3.85
6	Food services and drinking places	5.32	Financial investment services, funds and other financial vehicles	3.38
7	Petroleum refineries	4.41	Computer systems design and related services	2.96
8	Financial investment services, funds and other financial vehicles	3.91	Automobile and light-duty motor vehicle manufacturing	2.71
9	Insurance carriers	3.51	Food services and drinking places	2.64
10	Telecommunications	3.29	Other municipal government services	2.56
11	Meat product manufacturing	3.14	Other provincial and territorial government services	2.46
12	Repair construction	2.52	Insurance carriers	2.20
13	Food and beverage stores	2.36	Repair construction	2.08
14	Electric power generation, transmission and distribution	2.22	Other federal government services (except defence)	2.06
15	Universities	1.74	Machinery, equipment and supplies wholesaler-distributors	1.99
16	<b><i>Dairy product manufacturing</i></b>	1.68	Universities	1.89
17	Clothing and clothing accessories stores	1.57	Non-residential building construction	1.78
18	General merchandise stores	1.53	Lessors of real estate	1.75
19	Personal and household goods wholesaler-distributors	1.51	Truck transportation	1.53
20	<b><i>Truck transportation</i></b>	1.42	Personal and household goods wholesaler-distributors	1.49
<b>Total backward linkage</b>		<b>173.97</b>	<b>Total forward linkage</b>	<b>144.57</b>

The bolded-italicized industries indicate industries that are not present in Ontario’s households’ top 20 backward and forward linkages (discussed in Table 4.8). RoW and Ontario have 18 common backward linkages, while they have 20 common forward linkages within the top 20. This indicates that RoW’s households play a similar economic role to Ontario’s households despite being a small portion of Ontario. Total backward and forward linkages for households in RoW are both greater than 100%. This indicates that households are very important to RoW’s economy.

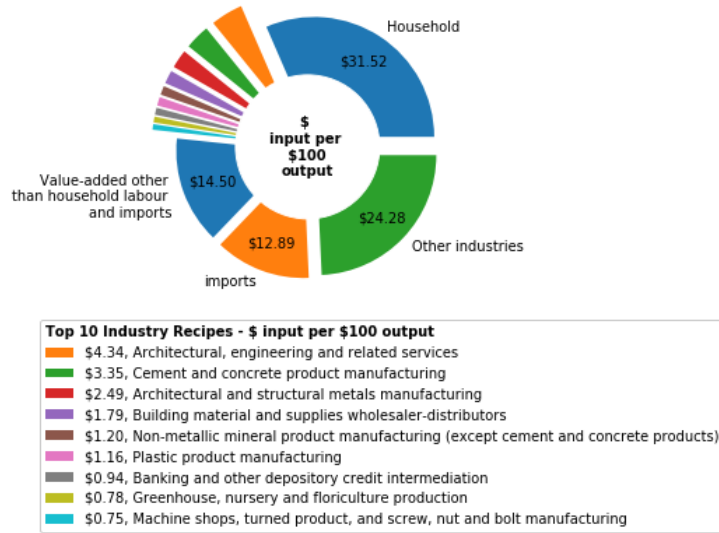
#### 4.4.1.4 Breakdown of intermediate inputs of building industries

Figure 4.21 illustrates the existing interindustry inputs (column(s) from the  $A^{rr}$  matrix) of the residential building construction industry for RoW. Regional technical input coefficients were used for analysis because it provides insight for RoW that the provincial Use matrix cannot. Figure 4.21 was divided into five segments: household labour, other value-added, imports, other intermediate inputs, and top 10 intermediate inputs. Results show that approximately 57% of interindustry input is from value-added (household labour, imports, and other value-added). Approximately 17% of residential construction inputs originate from 10 industries (listed in the legend of Figure 4.21) while the remaining 25% of inputs come from 226 different industries, and imports.



**Figure 4.21 – Region of Waterloo residential building construction recipe**

Figure 4.22 illustrates the existing interindustry inputs (column(s) from the  $A^{rr}$  matrix) of the non-residential building construction industry for RoW. Again, regional technical input coefficients were used for analysis because it provides insight for RoW that the provincial Use matrix cannot. Like residential construction, the non-residential construction recipe was divided into five segments. Figure 4.22 shows about 59% of interindustry inputs comes from value-added (household labour, imports, and other value-added). It is shown that non-residential building construction uses about 1% more household labour than residential building construction. The remaining 41% of inputs are made up of interindustry inputs, where approximately 17% of interindustry inputs are from 10 industries and the remaining 24% are from 226 industries. Like the Ontario commodity recipe, non-residential building construction uses more input from architecture and engineering services (about 4.3%) than residential building construction (about 1.7%).



**Figure 4.22 – Region of Waterloo non-residential building construction industry recipe**

Note that value-added proportions (other value added, and imports) are the same for each industry between RoW and Ontario. This is because regional ‘other value-added’, and ‘imports’ were assumed to have the same proportions as the provincial equivalents.

#### 4.4.2 Adjusting market share percentage

The effects of market share of adaptively reusable buildings on RoW’s total output were studied by varying the market share percentage in the basic scenario. That is,  $\beta$  was varied from 20%, 40%, 60%, and 80%, while non-structural components reused were fixed at 0%. Figure 4.23 summarizes the findings of market share effects on total output for RoW. Figure 4.23 shows that market share of adaptively reusable buildings has a linear effect on the total output changes for RoW. As market share increases, the effects on total output changes are magnified. From the plot for residential building construction, total output changes increase proportionately to the proportion of market share. For example, 40% market share of adaptively reusable residential buildings has doubled the effect on total output change than 20% market share. 60% market share has tripled the effect on total output change than 20% etc. This effect is expected as the two-region IRIO model is linear in nature.

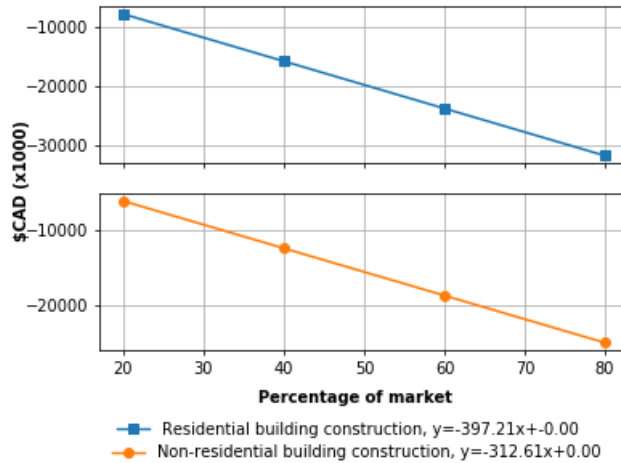


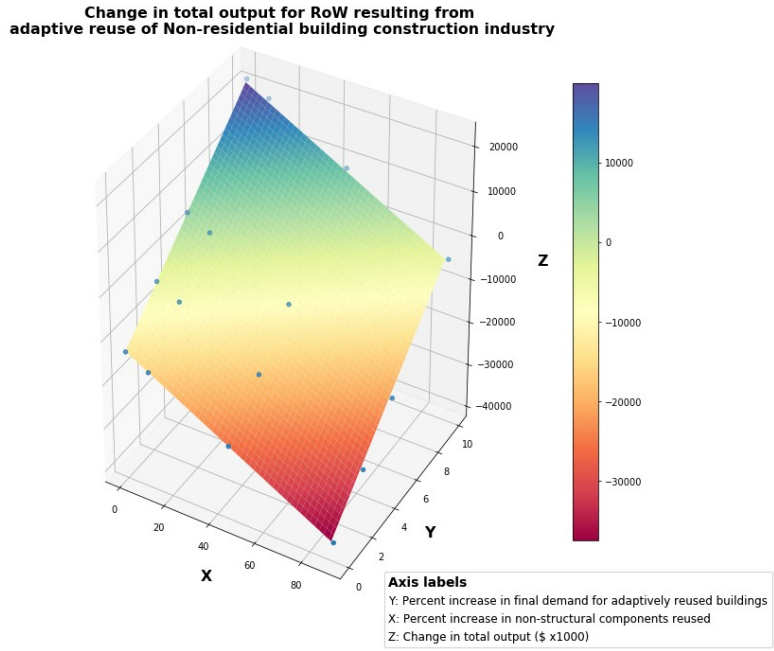
Figure 4.23 – Market share versus total output change for Region of Waterloo

#### 4.4.3 Adjusting percent of non-structural components reused and demand increase

Market share of buildings capable of AR were held constant at 20% (i.e.,  $\beta = 0.2$ ), while percentage of non-structural components reused, and increase in price for adaptively reused buildings varied. Recall that percentage of non-structural components reused varied from 0%, 10%, 45%, and 90%, and increase in price for adaptively reused buildings varies from 0%, 2.5%, 5% and 10%. Thus, a total of 16 scenarios were analyzed for AR of each building type in RoW.

##### 4.4.3.1 GDP, total output, total job, and total energy use changes

Recall that four measures of effectiveness were determined for the 16 scenarios (Table 4.1) for AR of each building industry. The results were plotted on a 3D scatter plot and a plane was fitted. A total of 8 3D plots for RoW were developed (4 measures of effectiveness by 2 industries) Figure 4.24 shows the 3D plot for change in total output in RoW resulting from AR of non-residential buildings as an example. In general, all plots show the similar characteristics. Total output, jobs, and energy use decreases relatively as the percentage of non-structural components reused increases. Also, total output, jobs, and energy use increases relatively as the price of AR buildings increases. On the other hand, GDP changes experience effects opposite to total output, jobs, and energy use. As percentage of non-structural components reused increases, so does GDP. Recall that the Use table records industry uses of domestic and imported commodities. Thus, reducing the commodity recipe reduces imports, consequentially GDP increases. Also, as the final demand for AR of residential or non-residential building increases, so does GDP. The remaining 3D plots for change in GDP, total output, total jobs, total energy use for RoW can be found in Appendix G.



**Figure 4.24 – Example of 3D plot – Region of Waterloo**

Visual comparison of 3D plots between Ontario and RoW does not show any obvious differences, except that the magnitudes of changes are larger for Ontario. Output vectors of Ontario and RoW were further investigated, and it was found that industrial output composition is different between Ontario and RoW. Figure 4.25 shows the percent of total output that each industry occupies in Ontario and RoW. Most industries occupy similar percentage of total output, except for manufacturing. Manufacturing occupies 24.0% and 38.1% of total output in Ontario and RoW, respectively. This notable difference results from the fact that 19.4% of RoW's total employment is in manufacturing, while 10.8% of Ontario's total employment is in manufacturing.

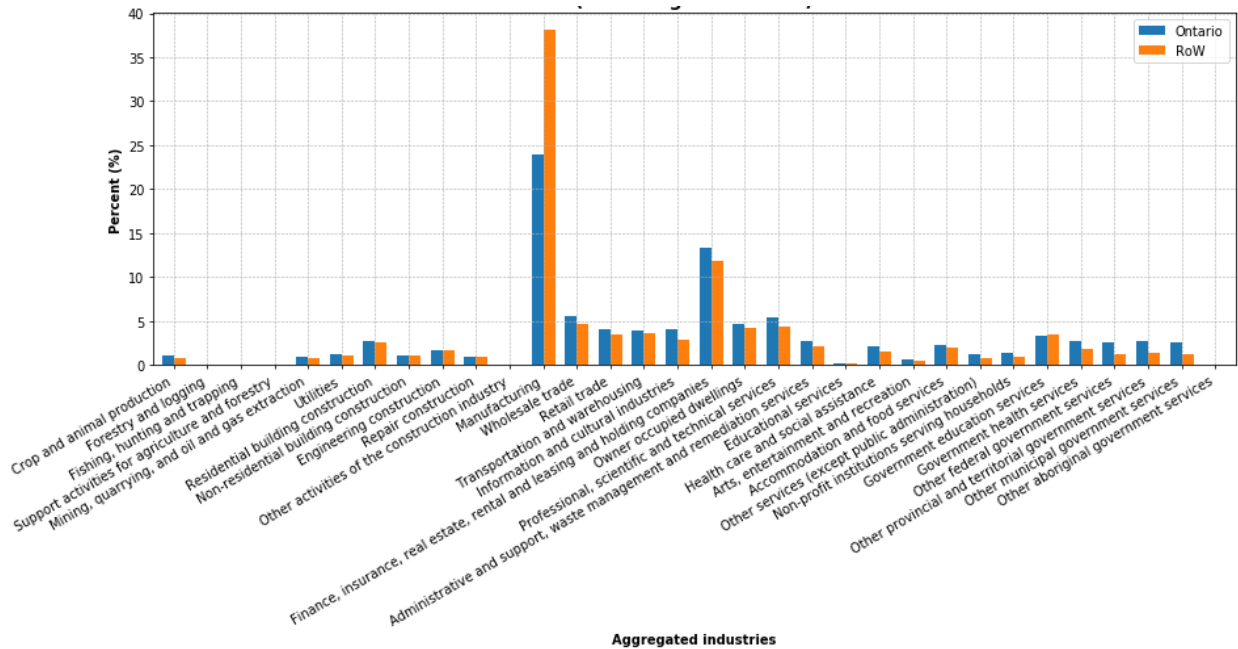


Figure 4.25 – Percent of total output that each industry occupies in Ontario and Region of Waterloo

#### 4.4.3.2 Positive and negative domains

The contours of the 3D plots were examined to determine the domain of X (percent non-structural components reused), and Y (increase in price of adaptively reused buildings) that results in negative changes to GDP, output, jobs, and energy consumption. Figure 4.26 shows an example plot of such domain for RoW. The remaining domain plots for RoW can be found in Appendix G.

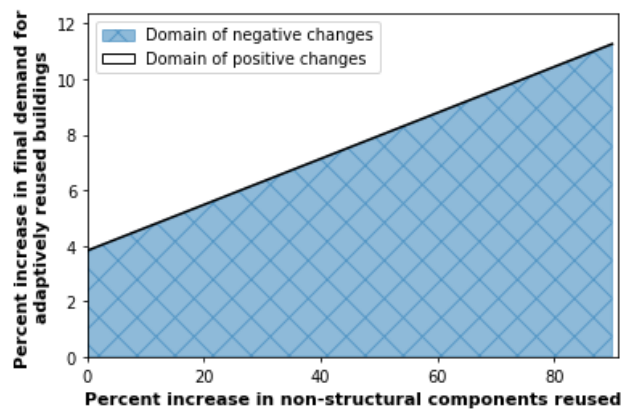


Figure 4.26 – Example of domain plot – Region of Waterloo

Domain plots for RoW are quite similar to the domain plots for Ontario. There is a common difference between domain plots for RoW and Ontario. Upon visual inspection, it appears that RoW has larger domains for negative changes than Ontario. In other words, the domain plots of Ontario are encompassed in domain plots of RoW. The larger domain is attributed to the fact that manufacturing occupies a larger portion of the

total output in RoW than in Ontario (shown in Figure 4.25). This indicates that if RoW experiences positive changes from AR, then Ontario does as well. On the other hand, if Ontario experiences positive changes from AR, it does not necessarily mean RoW experiences positive changes too.

The domain plots for RoW for all four measures of effectiveness were (output, GDP, jobs, energy) combined to determine the domain that is desirable with consideration of all four measures of effectiveness. Figure 4.27 and Figure 4.28 shows this desired domain for AR of non-residential and residential buildings in RoW. The desired domain is where change in energy use is negative, while change in GDP and jobs are positive. This domain lies in the area that is underneath the energy domain boundary, and above the domain boundaries of GDP, and jobs. Note that the GDP domain boundary is not present in Figure 4.27 and Figure 4.28 because GDP changes are positive for positive domains of X and Y.

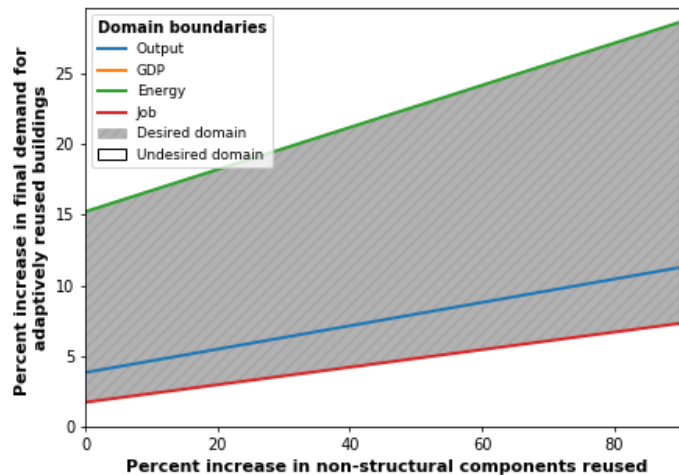


Figure 4.27 – Desired domain for adaptive reuse of non-residential building industry in Region of Waterloo

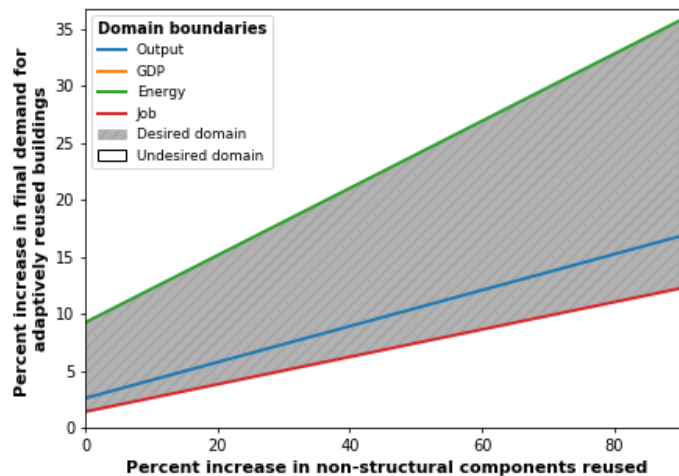


Figure 4.28 – Desired domain for adaptive reuse of residential building industry in Region of Waterloo



#### **4.4.3.3 Aggregated changes to output**

The output changes of AR of RoW building industries were examined further. Plots for aggregated changes to output for AR of each building industry and each scenario can be found in Appendix H. The percent changes to aggregated output for RoW are the same as Ontario. This is the direct result of the methodology used to estimate regional output. Recall that regional outputs were estimated using employment proportions and that AR recipe changes were applied at the provincial level. In other words, AR recipe changes were applied prior to regionalization. This results in regional output experiencing same output changes in percentage as the provincial output because regional output is directly proportionate to provincial output. Nonetheless, the plots aggregated output changes for RoW are shown in Appendix H.

#### **4.4.3.4 Top 10 increases and decreases in industry output**

Top 10 increases and decreases in industry output for RoW were examined for each scenario and summarized in tables found in Appendix I. Table 4.14 shows top 10 increases and decreases for 'Basic' scenario as an example.

Table 4.14 – Example of tables for top 10 increases and decreases in industry output

<b>RoW 'Basic' Scenario</b>						
<b>Top 10 decreases</b>						
<b>Ra nk</b>	<b>Industry</b>	<b>Residential building construction</b>		<b>Industry</b>	<b>Non-residential building construction</b>	
		<b>Total Industry Output (x \$1000)</b>	<b>Total Industry Output (%)</b>		<b>Total Industry Output (x \$1000)</b>	<b>Total Industry Output (%)</b>
1	Cement and concrete product manufacturing	-10162.18	-3.76	Cement and concrete product manufacturing	-6668.31	-2.47
2	Architectural and structural metals manufacturing	-4686.98	-1.30	Architectural and structural metals manufacturing	-3277.76	-0.91
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-214.52	-1.07	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-140.69	-0.70
4	Stone mining and quarrying	-109.75	-0.38	Stone mining and quarrying	-72.01	-0.25
5	Forging and stamping	-267.60	-0.36	Forging and stamping	-142.01	-0.19
6	Cutlery, hand tools and other fabricated metal product manufacturing	-526.12	-0.26	Boiler, tank and shipping container manufacturing	-145.56	-0.13
7	Other activities of the construction industry	-109.90	-0.19	Other activities of the construction industry	-71.05	-0.12
8	Boiler, tank and shipping container manufacturing	-212.19	-0.19	Non-metallic mineral product manufacturing (except cement and concrete products)	-251.18	-0.12
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-365.74	-0.17	Cutlery, hand tools and other fabricated metal product manufacturing	-218.61	-0.11
10	Machine shops, turned product, and screw, nut and bolt manufacturing	-283.60	-0.14	Alumina and aluminum production and processing	-136.69	-0.09
<b>Top 10 increases</b>						
<b>Ra nk</b>	<b>Industry</b>	<b>Residential building construction</b>		<b>Industry</b>	<b>Non-residential building construction</b>	
		<b>Total Industry Output (x \$1000)</b>	<b>Total Industry Output (%)</b>		<b>Total Industry Output (x \$1000)</b>	<b>Total Industry Output (%)</b>
1	Architectural, engineering and related services	1031.54	0.29	Architectural, engineering and related services	1114.76	0.31
2	Household	14063.66	0.10	Household	6870.03	0.05
3	Food, beverage and tobacco wholesaler-distributors	61.91	0.01	Food, beverage and tobacco wholesaler-distributors	73.18	0.02
4	Specialized design services	2.91	0.01	Specialized design services	4.70	0.01
5	Universities	26.28	0.00	Management, scientific and technical consulting services	15.25	0.01
6	Computer systems design and related services	17.70	0.00	Computer systems design and related services	37.41	0.00
7	Management, scientific and technical consulting services	1.54	0.00	Universities	29.64	0.00
8	Medical equipment and supplies manufacturing	0.55	0.00	Other professional, scientific and technical services	7.64	0.00
9	Other professional, scientific and technical services	0.43	0.00	Data processing, hosting, and related services	2.17	0.00
10	Private households	0.00	0.00	Medical equipment and supplies manufacturing	2.90	0.00

The list for RoW is identical to the list for Ontario. This is because the percent changes in industry output are the same between RoW and Ontario, as explained in Chapter 4.4.3.3. However, the magnitudes of the changes are different. Thus, generalization of top 10 increases and decreases in industry output for AR of each building type in RoW is outlined in Table 4.10 – Generalization of top 10 increases and decreases in industry output.

#### 4.5 Summary of results

Adaptive reuse of residential buildings and non-residential buildings were studied separately. 16 scenarios were analyzed for AR of each building type. First the ‘Basic’ scenario was defined, and then 15 other scenarios were defined based on the ‘Basic Scenario.’

The ‘Basic’ scenario represents the situation where only the building’s superstructure and substructure are reused. All internal non-structural components such as, drywall, furniture, HVAC, etc. were excluded. The changes made to the building industries recipe are grouped in three categories. First, the superstructure and substructure may be built with concrete or steel, or both, so reuse of the superstructure and substructure saves concrete and steel material. These savings in material costs are reflected in the building industries’ recipe change as a reduction of concrete and steel input. Second, reusing construction material ultimately reduces the transportation disposal costs, so transportation input of the building industries was reduced as well. Lastly, AR of building requires more labour than demolition. This is reflected in the recipe change as an increase of household labour input to the building industries.

The ‘Basic’ scenario was then altered to reflect the reuse of internal non-structural components. The percent of non-structural components reused was denoted as  $X$ . Four values were chosen for  $X$ : 0, 10, 40, and 90. Note that the ‘Basic’ scenario has  $X = 0$ . The ‘Basic’ scenario was further expanded to reflect increase in final demand of AR of each building type. The percent increase in final demand of AR buildings was denoted as  $Y$ . Four values were chosen for  $Y$ : 0, 2.5, 5, and 10. Note that the ‘Basic’ scenario has  $Y = 0$ . With  $X$  and  $Y$  having four values each, a 2D mesh with 16 points (scenarios) was examined for AR of each building industry. Each scenario was analyzed for a measure of effectiveness,  $Z$ , resulting in a 3D scatter plot. Next, the 3D scatter plot was fitted with a plane and analyzed.

Economic profiles of Ontario and RoW were examined prior to analyzing the impacts of AR of buildings. Hypothetical extraction, linkages and input breakdown were examined to understand the roles of the building industries in Ontario’s and RoW’s economy.

Hypothetical extraction of the building industries showed that they have similar roles in Ontario and RoW. Residential building construction is ranked within top 5 in total economic activity (in dollars and energy), while non-residential building is ranked between 17<sup>th</sup> and 23<sup>rd</sup> (in dollars and energy). Furthermore,

hypothetical extraction showed that residential building construction has a larger total economic activity than non-residential building construction in terms of dollars and energy (approximately doubled).

Backward linkages of the building industries show similar economic pull between each building industry and between Ontario and RoW. However, the notable differences in backward linkages between residential and non-residential buildings are that residential buildings have a stronger pull on wood related manufacturing, and non-residential buildings have a stronger pull on cement and concrete manufacturing, and architectural, engineering and related services. Total backward linkages of residential and non-residential building construction industries indicate that these industries have strong economic pull on other sectors in the economy. This finding aligns with the findings in Ren et al. (2014) and Song et al. (2006, 2008). Forward linkages for the building industries could not be found because industries do not use residential and non-residential building construction as intermediate inputs. Total forward linkages for the building industries found in this research also align with findings in Ren et al. (2014) and Song et al. (2006, 2008).

AR of buildings is expected to increase labour, so backward and forward linkages were examined for households. Households have strong economic pull on financial, food, energy, and communications related industries. On the other hand, households have strong economic push on health, education, housing, and government related industries.

The existing compositions of intermediate inputs for the building industries were examined. It was found that value-added comprises 62-64% of the building industries' input. More specifically 30-37% of inputs are household labour, while 32-37% is other value-added, and imports. The remaining inputs are commodities where 10 commodity/industries make up 14-19% of all inputs, and 19-22% of all inputs are 216 industries/472 commodities.

Scenarios of AR for residential and non-residential buildings were examined after economic profiles of Ontario and RoW were established. First, the effects of AR market share were analyzed. Next, measures of effectiveness were determined for 16 scenarios of AR of each building type in Ontario and RoW. Finally, detailed industry changes were examined for the 16 scenarios of each building type for Ontario and RoW.

Adjusting the percent of the building industries that implements AR has shown to have linear effects on measures of effectiveness. For example, if output changes are positive then increasing the market share of AR buildings positively magnifies the changes linearly. On the other hand, if output changes are negative then increasing market share of AR buildings negatively magnifies the changes linearly.

The four measures (output, GDP, jobs, energy) were examined for 16 scenarios for AR of each building type for Ontario and RoW. The results were plotted on a 3D scatter plot, and then a plane was fitted to the 3D scatter points. Change in output, jobs, and energy use decreases as more non-structural components are

reused. Contrarily, output, jobs and energy use increase as final demand increases. GDP is an exception because it increases when non-structural components are reused and/or final demand increases.

Contour plots of the 3D planes were examined to find the domains that result in negative changes to the measures of effectiveness. Negative changes to GDP and jobs are undesirable, while negative changes to energy use are desirable. Output, jobs, and energy use exhibit domains of negative change, but GDP does not as the 3D planes for GDP are positive for all scenarios. The domains of the four measures of effectiveness were combined to determine the domain that produces desirable effects to all measures of effectiveness. The desirable domain was defined where changes to energy uses are negative, while changes to GDP and jobs are positive. The desired domain implies that adaptive reuse of buildings needs to be accompanied by an increased demand for it to be beneficial for regional economies. It is not enough to only adaptively reuse buildings and reuse construction material as it only reduces industrial output and employment of industries producing new construction materials.

Top 10 increases and decreases to industry outputs were analyzed to understand the detailed effects that AR of buildings has on Ontario and RoW. It was found that industry output changes were same between Ontario and RoW in terms of percentage. This is the result of estimating RoW outputs from Ontario outputs using employment proportions. However, in terms of dollar changes, Ontario exhibits larger changes as expected. Generally, industries that experience negative changes to output are industries that provide intermediate inputs to concrete and structural steel manufacturing. Also, industries that experience positive changes are generally industries that have strong linkages to households.

## 5 Conclusion

The construction industry has large impacts on the environment due to its consumption of raw materials, energy, and water. The AR of buildings can help the construction industry improve environmental sustainability. AR is a construction method that fundamentally changes the production function of the construction industry. Since the construction industry is an integral part of the economy, these changes may have impacts that propagate throughout the economic system. Thus, not only is it important to study the impacts of AR on the construction industry, it is also important to study the impacts that AR of buildings has on the other sectors of the economy.

The literature review of AR yielded little to no indication of its impacts on the economy. Instead, literature on AR is mostly comprised of qualitative studies. Qualitative studies include advantages and disadvantages/barriers of AR; decision making tools and guidelines for seeking prospective candidates of AR; and ex-post case studies of AR buildings. There are a plethora of studies discussing the economic benefits (as well as environmental and social benefits) of AR, but there is a lack of studies quantifying these effects. Studies that do investigate the economics of AR are limited to project scale analyses (i.e., financial feasibility or cost benefit analysis). In the case of Canada, Stas (2007) confirms “that there is a lack of studies about the economic impacts of AR on the economy.”

The lack of studies regarding the economic impacts of AR reduced the literature review to studies on the relationship of the construction industry and the economy. More specifically, the literature review focused on studies that implemented IO models in studying construction industries and relevant topics. Research on the construction industry using IO models has looked at the industry’s embodied energy using Structural Path Analysis, technological change over time using Structural Decomposition Analysis, and linkages with other industries using Hypothetical Extraction Method and other methods. None of these studies focused on the AR of buildings. The only study that hints at AR was conducted by Pietroforte et al. (2009). Their study concludes that the impacts of innovative technologies on the construction industry require further investigation. To further expand, Pietroforte et al. (2009) recommends that structural changes in an economy resulting from the construction industry should be considered:

“the impact of factors such as changes in the characteristics of construction projects (e.g. more bathrooms in residential projects), changes in architectural and engineering design, increased mechanization, the use of new materials and related substitution.” (Pietroforte et al., 2009)

Although not intended, Pietroforte et al. (2009) stated the knowledge gap of AR in the construction industry from an economic impact perspective. Hence, this research aimed to study the economic impacts of AR of buildings on a regional economy. The region that was chosen for this study was Region of Waterloo in Ontario, Canada.

## 5.1 Contributions and Key Findings

The economic modelling technique used to study regional economic impacts of AR of buildings is an IO model. First, a symmetric IO model of the province of Ontario was developed for the base economy using Statistics Canada's 2014 make-and-use data. This base case IO model was scrubbed of imports, so that only the domestic economy remained. Next, households were endogenized in the domestic Ontario IO model, so that induced effects of households spending were captured. Then, the Ontario IO model was regionalized into a two-region IRIO model using cross industry location quotients to estimate regional input coefficients, and employment data to estimate regional outputs. After the base case IO model was developed, scenarios for AR were created by first changing the building industries recipe in the make-and-use data, then proceeding with model development similar to the base case IO model. In other words, AR was implemented for the entire province. As a result, 32 IO models were created to reflect various levels of AR and final demand increases. The 32 scenarios were applied to the provincial IO model, and the two-region IRIO model, so that economic impacts to Ontario and RoW could be compared.

Contrary to literature stating the environment and economy benefit from the AR of buildings, this research has shown that results can vary. That is, there are combinations of final demand increases and levels of non-structural components reuse that result in negative impacts to the environment (energy consumption) and economy (employment). In other words, this research has shown that AR of buildings and reuse of construction material may not bring economic benefits, since it would only reduce employment in industries supplying construction materials. Adaptive reuse may be beneficial to an economy on the condition that there is an increase in demand of adaptively reused buildings. Increasing demand for AR building construction may be achieved by addressing barriers of implementing AR (outlined in chapter 2.2). The only measure of effectiveness that did not experience negative impacts in any scenario analyzed is GDP. GDP is expected to increase, since AR reduces intermediate inputs, and hence consequently reduces a portion of imports. Furthermore, there are certain conditions where AR may reduce total energy consumption, but employment and output decrease as well, and vice versa.

Song et al. (2006) suggested that increasing demand of the construction industry creates large number of jobs due the industry's strong backward linkages with other sectors in the economy. Scenario analyses of adaptive reuse on changes in total employment agree with Song et al. (2006) (i.e., increasing demand of adaptive reuse building construction increases total employment). However, this increase in employment may be counteracted with employment losses due to decrease in the output of industries resulting from reduced reliance on new construction materials. By plotting domain plots of negative change for total output, GDP, energy use, and employment, this research depicts the combination of final demand increase (Y) and percent non-structural components reused (X) that result in unfavourable outcomes to GDP and employment, and favourable outcomes to energy consumption. In addition, the domain plots consequently outline the domains

of positive change in GDP, energy use, and employment. Hence, the domain plots outline the combination of X's and Y's that result in favourable outcomes to GDP and employment, and unfavourable outcomes to energy consumption.

Detailed findings of industrial output changes show that as the quantity of AR buildings or level of AR increases, concrete and steel industry outputs decrease, as well as their intermediate inputs such as those from the mining and quarrying industries. The outputs of forestry industries are expected to decrease as the quantity and level of residential AR buildings increase (industrial buildings adaptively reused into residential buildings). The manufacturing industry is expected to decrease their output as the level of AR increases. In other words, as more internal non-structural components of a building are reused, manufacturing output decreases. By endogenizing households in the model, it is shown that increasing labour for the building construction industry will have economic multiplier effects on the economy. That is, outputs of professional services, entertainment and recreation, education, health, and government services increase as a result of more labour income (and spending).

## **5.2 Limitations and future Research**

As consequences of implementing an IO model for this research, price effects and resource constraints are unaccounted for. Reuse of construction material may alter prices of new construction material. For example, suppliers of new construction material may lower their prices to remain competitive with reused/recycled construction material. On the other hand, price of construction material may go up if resource becomes scarce. Price effects are not captured in an IO model due to the assumption of fixed technical coefficients. Moreover, IO models allow unbounded final demand changes, since there are no supply constraints imposed. This is not always realistic, since resources can be limited.

An issue that was encountered when modelling the recipe changes to the building industries is the lack of quantitative information regarding AR projects. Moreover, quantitative information found in the existing literature varies substantially. For example, the percentage of non-structural component reuse may range from 10% to 90%. Due to limited information on AR projects, the economic model implemented in this study assumed uniform reductions to all non-structural components reused. However, this may not be representative of real-world scenarios. For example, the percentage of windows reused may not be the same as percentage of office furniture reused, etc. Future studies may investigate in detail the quantity and/or price of each commodity saved.

This research assumed that AR affects Ontario and RoW uniformly (i.e., industry recipe, labour, and final demand experience the same changes). Again, this may not be representative of real-world situations, as regions may vary in their production technologies and local demands. For example, it was shown that RoW has a higher manufacturing output composition than Ontario. Future studies may investigate how regional



differences affect AR of buildings. In addition, this research assumed that AR affects each building industry uniformly (i.e., industry recipe, labour, and final demand experiences the same changes. This may not be representative of real world, since characteristics of residential and non-residential buildings are different.

Lastly, future economic impact studies of AR may use different economic models to address limitations of IO models and/or compare results found in this research. For example, a Computable General Equilibrium (CGE) model can include price effects and supply constraints, making it a suitable method to study long-term impacts, or for studying large and widespread shifts in construction practices that are likely to require those model features.

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## Appendix A – Commodity, industry, final demand, imports, exports, and value-added labels

Table A1 – Commodity labels at summary and detailed level

Commodity at summary level	Commodity at detailed level
<b>Grains and other crop products</b>	Canola (including rapeseed)
	Oilseeds (except canola)
	Wheat
	Grains (except wheat)
	Fresh potatoes
	Fresh fruits and nuts
	Other miscellaneous crop products
	Fresh vegetables (except potatoes)
	Imputed feed (animal feed produced for own consumption)
Nursery and floriculture products	
<b>Live animals</b>	Cattle and calves
	Unprocessed fluid milk
	Hogs
	Eggs in shell
	Poultry
<b>Other farm products</b>	Other live animals
	Raw furskins, and animal products n.e.c.
<b>Forestry products and services</b>	Imputed fertilizer (fertilizer produced for own consumption)
	Logs and bolts
	Pulpwood
	Fuel wood
<b>Fish, crustaceans, shellfish and other fishery products</b>	Rough untreated poles, posts and piling
	Fish, crustaceans, shellfish and other fishery products
<b>Support services related to farming and forestry</b>	Custom work services for forestry
	Support services for crop production
	Support services for animal production, hunting and fishing
	Support services for forestry
<b>Mineral fuels</b>	Conventional crude oil
	Synthetic crude oil
	Natural gas
	Natural gas liquids and related products
	Crude and diluted bitumen
<b>Metal ores and concentrates</b>	Coal
	Iron ores and concentrates

	Gold and silver ores and concentrates
	Copper ores and concentrates
	Nickel ores and concentrates
	Lead and zinc ores and concentrates
	Radioactive ores and concentrates
	Other metal ores and concentrates
<b>Non-metallic minerals</b>	Stone
	Sand, gravel, clay, and refractory minerals
	Uncut and industrial diamonds
	Potash
	Non-metallic minerals (except diamonds)
<b>Mineral support services</b>	Support services for oil and gas extraction (except exploration)
	Support services for mining and quarrying (except exploration)
<b>Mineral and oil and gas exploration</b>	Mineral and oil and gas exploration
<b>Utilities</b>	Electricity
	Natural gas distribution
	Water delivered by water works and irrigation systems
	Sewage and dirty water disposal and cleaning services
	Steam and heated or cooled air or water
<b>Residential construction</b>	Residential construction
<b>Non-residential buildings</b>	Industrial buildings
	Office buildings
	Shopping centers, plazas, malls and stores
	Other commercial buildings
	Schools, colleges, universities and other educational buildings
	Health care buildings
	Other institutional buildings
<b>Engineering construction</b>	Highways, roads, streets, bridges and tunnels
	Other transportation construction
	Production facilities in oil and gas extraction
	Other oil and gas engineering construction
	Electric power engineering construction
	Communication engineering construction
	Marine engineering construction
	Waterworks engineering construction
	Sewage engineering construction
	Mining engineering construction
	Other engineering construction
<b>Repair construction services</b>	Repair construction services
<b>Food and non-alcoholic beverages</b>	Dog and cat food



	Other animal feed
	Flour and other grain mill products
	Margarine and cooking oils
	Breakfast cereal and other cereal products
	Grain and oilseed products, n.e.c.
	Sugar and sugar mill by-products
	Chocolate (except confectionery)
	Confectionery products
	Fresh, frozen and canned fruit and vegetable juices
	Preserved fruit and vegetables and frozen foods
	Processed fluid milk and milk products
	Cheese and cheese products
	Butter and dry and canned dairy products
	Ice cream, sherbet and similar frozen desserts
	Fresh and frozen beef and veal
	Fresh and frozen pork
	Fresh and frozen poultry of all types
	Processed meat products, other miscellaneous meats and animal by-products
	Prepared and packaged seafood products
	Bread, rolls and flatbreads
	Cookies, crackers and baked sweet goods
	Flour mixes, dough and dry pasta
	Snack food products
	Coffee and tea
	Flavouring syrups, seasonings and dressings
	Other food products, n.e.c.
	Bottled water, soft drinks and ice
<b>Alcoholic beverages and tobacco products</b>	Beer
	Wine and brandy
	Distilled liquor
	Stemmed, redried or reconstituted tobacco
	Cigarettes, cigars, chewing and smoking tobacco
<b>Textile products, clothing, and products of leather and similar materials</b>	Fibre, yarn and thread
	Fabrics
	Carpets, rugs and mats
	Other textile furnishings
	Textile products, n.e.c.
	Textile and fabric finishing and coating services

	Men's, women's, boys' and girls' clothing
	Infant clothing
	Clothing accessories
	Leather and dressed furs
	Footwear
	Suitcases, handbags and other leather and allied products
<b>Wood products</b>	Hardwood lumber
	Softwood lumber
	Wood chips
	Other sawmill products and treated wood products
	Veneer and plywood
	Wood trusses and engineered wood members
	Reconstituted wood products
	Wood windows and doors
	Wood containers and pallets
	Prefabricated wood and manufactured (mobile) buildings and components
	Wood products, n.e.c.
	Waste and scrap of wood and wood by-products
<b>Wood pulp, paper and paper products and paper stock</b>	Wood pulp
	Paper (except newsprint)
	Newsprint
	Paperboard
	Paperboard containers
	Paper office supplies
	Disposable diapers and feminine hygiene products
	Sanitary paper products
	Other converted paper products
	Waste and scrap of paper and paperboard
<b>Printed products and services</b>	Printed products
	Support services for printing
	Contract printing services for publishers
<b>Refined petroleum products (except petrochemicals)</b>	Gasoline
	Diesel and biodiesel fuels
	Light fuel oils
	Jet fuel
	Heavy fuel oils
	Lubricants and other petroleum refinery products
	Asphalt (except natural) and asphalt products
	Coke and other coke oven products

	Solid fuel products, n.e.c.
<b>Chemical products</b>	Petrochemicals
	Industrial gases
	Dyes and pigments
	Other basic inorganic chemicals
	Basic organic chemicals, n.e.c.
	Plastic resins
<b>Plastic and rubber products</b>	Rubber and rubber compounds and mixtures
	Artificial and synthetic fibres and filaments
	Ammonia and chemical fertilizers
	Pesticides and other agricultural chemicals
	Pharmaceutical and medicinal products
	Paints, coatings and adhesive products
	Soaps and cleaning compounds
	Perfumes and toiletries
	Chemical products, n.e.c.
	Plastic bags
	Plastic films and non-rigid sheets
	Plastic and foam building and construction materials
	Plastic profile shapes
	Foam products (except for construction)
	Plastic bottles
	Motor vehicle plastic parts
	Plastic products, n.e.c.
	Tires
	Rubber and plastic hoses and belts
	Rubber products, n.e.c.
	Waste and scrap of plastic and rubber
<b>Non-metallic mineral products</b>	Cement
	Ready-mixed concrete
	Concrete products
	Clay and ceramic products and refractories
	Glass (including automotive), glass products and glass containers
	Waste and scrap of glass
	Lime and gypsum products
	Non-metallic mineral products, n.e.c.
<b>Primary metallic products</b>	Iron and steel basic shapes and ferro-alloy products
	Iron and steel pipes and tubes (except castings)
	Wire and other rolled and drawn steel products
	Bauxite and aluminum oxide

	Unwrought aluminum including alloys
	Basic and semi-finished products of aluminum and alloys
	Unwrought copper including alloys
	Unwrought nickel including alloys
	Unwrought precious metals including alloys
	Other unwrought non-ferrous metals including alloys
	Gold, store of value
	Basic and semi-finished products of non-ferrous metals and alloys (except aluminum)
	Ferrous metal castings
	Non-ferrous metal castings
	Waste and scrap of iron and steel
	Waste and scrap of non-ferrous metals
<b>Fabricated metallic products</b>	Forged and stamped metal products
	Prefabricated metal buildings and components
	Fabricated steel plates and other fabricated structural metal
	Metal windows and doors
	Other architectural metal products
	Light gauge metal containers, crowns and closures
	Boilers, tanks and heavy gauge metal containers
	Builders, motor vehicle and other hardware
	Springs and wire products
	Threaded metal fasteners and other turned metal products including automotive
	Coating, engraving, heat treating and similar metal processing services
	Hand tools, kitchen utensils and cutlery (except precious metal)
	Metal valves and pipe fittings
	Ball and roller bearings
	Guns, ammunition and other munitions
	Fabricated metal products, n.e.c.
<b>Industrial machinery</b>	Agricultural, lawn and garden machinery and equipment
	Logging, mining and construction machinery and equipment
	Other industry-specific machinery
	Commercial and service industry machinery
	Industrial and commercial fans, blowers and air purification equipment
	Heating and cooling equipment (except household refrigerators and freezers)
	Metalworking machinery and industrial moulds
	Turbines, turbine generators, and turbine generator sets
	Other engine and power transmission equipment
	Pumps and compressors (except fluid power)

	Material handling equipment
	Other miscellaneous general-purpose machinery
<b>Computers and electronic products</b>	Computers, computer peripherals and parts
	Telephone apparatus
	Other communications equipment
	Audio and video equipment and unrecorded media
	Navigational and guidance instruments
	Medical devices
	Measuring, control and scientific instruments
	Printed and integrated circuits, semiconductors and printed circuit assemblies
	Other electronic components
<b>Electrical equipment, appliances and components</b>	Electric light bulbs and tubes
	Lighting fixtures
	Small electric appliances
	Major appliances
	Power, distribution and other transformers
	Electric motors and generators
	Switchgear, switchboards, relays and industrial control apparatus
	Batteries
	Communication and electric wire and cable
	Wiring devices
	Other electrical equipment and components
<b>Transportation equipment</b>	Passenger cars
	Light-duty trucks, vans and sport utility vehicles (SUVs)
	Medium and heavy-duty trucks and chassis
	Buses
	Motor vehicle bodies and special purpose motor vehicles
	Freight and utility trailers
	Motor homes, travel trailers and camping trailers
<b>Motor vehicle parts</b>	Motor vehicle gasoline engines and engine parts
	Motor vehicle electrical and electronic equipment and instruments
	Motor vehicle steering and suspension components
	Motor vehicle brakes and brake systems
	Motor vehicle transmission and power train parts
	Motor vehicle interior trim, seats and seat parts
	Motor vehicle metal stamping
	Other miscellaneous motor vehicle parts
	Aircraft
	Aircraft engines

	Aircraft parts and other aerospace equipment
	Locomotives, railway rolling stock, and rapid transit equipment
	Parts of railway rolling stock
	Ships
	Boats and personal watercraft
	Other transportation equipment and related parts
<b>Furniture and related products</b>	Wood kitchen cabinets and counter tops
	Household furniture
	Institutional and other furniture, n.e.c.
	Office furniture
	Office and store fixtures
	Mattresses and foundations
	Blinds and shades
	Medical, dental and personal safety supplies, instruments and equipment
	Jewellery and silverware
	Sporting and athletic goods
	Toys and games
	Office supplies (except paper)
	Signs
<b>Other manufactured products and custom work</b>	Other miscellaneous manufactured products
	Custom work manufacturing services (except printing, finishing textiles and metals)
<b>Wholesale margins and commissions</b>	Wholesale margins - farm products
	Wholesale margins - petroleum and petroleum products
	Wholesale margins - food, beverages and tobacco products
	Wholesale margins - personal and household goods
	Wholesale margins - motor vehicles, motor vehicle parts and accessories
	Wholesale margins - building materials and supplies
	Wholesale margins - machinery, equipment and supplies
	Wholesale margins - miscellaneous products
	Wholesale trade commissions
<b>Retail margins, sales of used goods and commissions</b>	Retail margins - motor vehicles and parts
	Retail margins - furniture and home furnishings
	Retail margins - electronics and appliances
	Retail margins - building materials, garden equipment and supplies
	Retail margins - food and beverages
	Retail margins - health and personal care products
	Retail margins - automotive fuels
	Retail margins - clothing and clothing accessories
	Retail margins - sporting and leisure products

	Retail margins - miscellaneous products
	Retail margins - household fuels
	Used motor vehicles
	Other used consumer goods
	Retail trade commissions
<b>Transportation and related services</b>	Air passenger transportation services
	Air freight transportation services
	Air specialty services
	Rail passenger transportation services
	Rail freight transportation services
	Water passenger transportation services
	Water freight transportation services
	Moving services
	Truck transportation services for general freight
	Truck transportation services for specialized freight
	Urban transit services
	Interurban and rural bus passenger transportation services
	School bus services
	Other transit and passenger transportation services by road
	Scenic and sightseeing tour services
	Taxi and limousine services
	Transportation of natural gas by pipeline
	Transportation of crude oil and other commodities by pipeline
	Air transportation support services
	Aircraft maintenance and repair services
	Rail transportation support, maintenance and repair services
	Water transportation support, maintenance and repair services
	Road transportation support services
	Freight transportation arrangement and customs brokering services
	Other transportation support services
<b>Information and cultural services</b>	Postal services
	Courier, parcel, and local messenger and delivery services
	Grain storage
	Warehousing and storage services (except grain storage)
<b>Published and recorded media products</b>	Newspapers
	Advertising space in printed newspapers
	Periodicals
	Books
	Other published products

	Advertising space in printed periodicals and in other printed publications
	Licensing of rights to use literary works and artistic works (except software licensing)
	General purpose software
<b>Telecommunications</b>	Recorded movies, television programs and videos
	Movie, television program and video production, post-production and editing services
	Licensing of rights to use audiovisual works
	Admissions to motion picture film exhibitions
	Recorded music and other sound recordings
	Audio recording services and copyright administration
	Licensing of rights to use musical works and sound recordings
	Advertising air time on radio
	Advertising air time on television
	Fees for the distribution of television and radio program channels (affiliation payments)
	Fixed telecommunications services (except Internet access)
	Mobile telecommunications services
	Cable, satellite and other program distribution services
<b>Depository credit intermediation</b>	Fixed Internet access services
	Data processing, hosting, and related services
	Subscriptions for online content
	Internet advertising
	Other information services
	Central banking services
	Local credit union services - explicit charges (fees)
	Banking and other depository credit intermediation services - explicit charges
	Non-depository credit intermediation services - explicit charges (fees)
	Other services related to credit intermediation
<b>Other finance and insurance</b>	Investment banking services
	Security brokerage and securities dealing services
	Portfolio management services
	Investment counselling services
	Holding company services and other financial investment and related activities
	Life insurance services
	Accident and sickness insurance services
	Automotive insurance services
	Property insurance services
	Liability and other property and casualty insurance services



	Brokerage and other insurance related services
	Trusted pension fund services
	Mutual funds (cost of service) and other similar services
	Deposit intermediation services indirectly measured (FISIM)
	Residential mortgage intermediation services indirectly measured (FISIM)
	Other loan intermediation services indirectly measured (FISIM)
<b>Real estate, rental and leasing and rights to non-financial intangible assets</b>	Rental of residential real estate
	Rental of non-residential real estate
<b>Imputed rental of owner-occupied dwellings</b>	Imputed rental of owner-occupied dwellings
	Real estate brokerage and other services related to real estate
<b>Professional services (except software and research and development)</b>	Motor vehicle rental and leasing services
	Computer equipment rental and leasing services
	Office machinery and equipment (except computer equipment) rental and leasing services
	Commercial and industrial machinery and equipment (except office equipment) rental and leasing services
	Rental and leasing services of other goods
	Licensing of rights to non-financial produced intangible assets (except software and other copyright licensing)
	Legal services
	Accounting, tax preparation, bookkeeping and payroll services
	Architectural, engineering and related services
	Specialized design services
	Computer systems design and related services (except software development)
	Management, scientific and technical consulting services
	Own-account research and development (except software development)
	Advertising, public relations and related services
	Photographic services
	Veterinary services
	Other professional, scientific and technical services
<b>Software</b>	Custom software design and development services
	Own-account software design and development services
<b>Research and development</b>	Research and development services
<b>Administrative and support, head office, waste management and remediation services</b>	Holding company services (imputed)
	Head office services (imputed)
	Office administrative services
	Employment services

	Business support services
	Travel arrangement, reservation and planning services
	Investigation and security services
	Services to buildings and dwellings
	Facilities and other support services
	Waste management and remediation services
<b>Education services</b>	Tuition and similar fees for elementary and secondary schools
	Tuition and similar fees for colleges and C.E.G.E.P.s
	Tuition and similar fees for universities
	Tuition and similar fees for trade, technical and professional training
	Other educational training and services
<b>Health and social assistance services</b>	Physician services
	Dental services
	Other health practitioner services
	Medical laboratory diagnostic and testing services
	Ambulance services
	Hospital services
	Nursing and residential care services
	Child day-care services
	Other ambulatory health care services and social assistance services
<b>Arts, entertainment and recreation services</b>	Admissions to live sporting events
	Admissions to live performing arts performances
	Sport and performing arts event organization and support services
	Career management and representation services of public figures
	Contract production of live performing arts performances, live sporting events and copyrighted works
	Broadcast and other media rights
	Heritage institution services
	Amusement and recreation services
	Gambling (net wagers)
<b>Accommodation and food services</b>	Room or unit accommodation services for travellers
	Recreational vehicle park and recreational camp services
	Rooming and boarding services
	Prepared meals
	Alcoholic beverages for immediate consumption
<b>Other services</b>	Motor vehicle repair and maintenance services
	Repair and maintenance services (except for buildings and motor vehicles)
	Funeral services
	Laundry and dry-cleaning services

	Hair care and aesthetic services
	Parking services
	Other personal and personal care services
	Other membership services
	Babysitting services
	Private household services (except babysitting)
<b>Sales of other services by Non-Profit Institutions Serving Households</b>	Sales of other services by Non-Profit Institutions Serving Households
<b>Sales of other government services</b>	Sales of other government services
	Repair and maintenance
<b>Fictive materials</b>	Operating supplies
	Office supplies
<b>Fictive services</b>	Advertising, promotion, meals and entertainment
	Travel, meetings and conventions
<b>Transportation margins</b>	Transportation margins
<b>Services provided by Non-Profit Institutions Serving Households</b>	Educational services provided by Non-Profit Institutions Serving Households
	Ambulatory health care services provided by Non-Profit Institutions Serving Households
	Social assistance services provided by Non-Profit Institutions Serving Households
	Arts, entertainment and recreation services provided by Non-Profit Institutions Serving Households
	Religious services
	Grant-making, civic, and professional and similar organization services
	Labour organization membership services
	Political organization services
	Other services provided by Non-Profit Institutions Serving Households
<b>Education services provided by government sector</b>	Elementary and secondary school services provided by governments
	Community college and C.E.G.E.P services provided by governments
	University services provided by governments
	Other educational services provided by governments
<b>Health services provided by government sector</b>	Hospital services provided by governments
	Residential care facility services provided by governments
<b>Other federal government services</b>	Defence services
	Other federal government services
<b>Other provincial and territorial government services</b>	Other provincial and territorial government services
<b>Other municipal government services</b>	Other municipal government services
<b>Other aboriginal government services</b>	Other aboriginal government services

**Table A2 – Industry labels at summary and detailed level**

<b>Industries at summary level</b>	<b>Industries at detailed level</b>
<b>Crop and animal production</b>	Business sector, Crop production (except greenhouse, nursery and floriculture production)
	Business sector, Greenhouse, nursery and floriculture production
	Business sector, Animal production (except aquaculture)
	Business sector, Aquaculture
<b>Forestry and logging</b>	Business sector, Forestry and logging
<b>Fishing, hunting and trapping</b>	Business sector, Fishing, hunting and trapping
<b>Support activities for agriculture and forestry</b>	Business sector, Support activities for crop and animal production
	Business sector, Support activities for forestry
<b>Mining, quarrying, and oil and gas extraction</b>	Business sector, Conventional oil and gas extraction
	Business sector, Gold and silver ore mining
	Business sector, Copper, nickel, lead and zinc ore mining
	Business sector, Other metal ore mining
	Business sector, Stone mining and quarrying
	Business sector, Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying
	Business sector, Diamond mining
	Business sector, Other non-metallic mineral mining and quarrying (except diamond and potash)
	Business sector, Support activities for oil and gas extraction
	Business sector, Support activities for mining
<b>Utilities</b>	Business sector, Electric power generation, transmission and distribution
	Business sector, Natural gas distribution
	Business sector, Water, sewage and other systems
<b>Residential building construction</b>	Business sector, Residential building construction
<b>Non-residential building construction</b>	Business sector, Non-residential building construction
<b>Engineering construction</b>	Business sector, Transportation engineering construction
	Business sector, Oil and gas engineering construction
	Business sector, Electric power engineering construction
	Business sector, Communication engineering construction
	Business sector, Other engineering construction
<b>Repair construction</b>	Business sector, Repair construction
<b>Other activities of the construction industry</b>	Business sector, Other activities of the construction industry
<b>Manufacturing</b>	Business sector, Animal food manufacturing
	Business sector, Grain and oilseed milling
	Business sector, Sugar and confectionery product manufacturing
	Business sector, Fruit and vegetable preserving and specialty food manufacturing
	Business sector, Dairy product manufacturing

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Business sector, Meat product manufacturing
Business sector, Seafood product preparation and packaging
Business sector, Bakeries and tortilla manufacturing
Business sector, Other food manufacturing
Business sector, Soft drink and ice manufacturing
Business sector, Breweries
Business sector, Wineries and distilleries
Business sector, Tobacco manufacturing
Business sector, Textile and textile product mills
Business sector, Clothing and leather and allied product manufacturing
Business sector, Sawmills and wood preservation
Business sector, Veneer, plywood and engineered wood product manufacturing
Business sector, Other wood product manufacturing
Business sector, Pulp, paper and paperboard mills
Business sector, Converted paper product manufacturing
Business sector, Printing and related support activities
Business sector, Petroleum refineries
Business sector, Petroleum and coal product manufacturing (except petroleum refineries)
Business sector, Basic chemical manufacturing
Business sector, Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing
Business sector, Pesticide, fertilizer and other agricultural chemical manufacturing
Business sector, Pharmaceutical and medicine manufacturing
Business sector, Paint, coating and adhesive manufacturing
Business sector, Soap, cleaning compound and toilet preparation manufacturing
Business sector, Other chemical product manufacturing
Business sector, Plastic product manufacturing
Business sector, Rubber product manufacturing
Business sector, Non-metallic mineral product manufacturing (except cement and concrete products)
Business sector, Cement and concrete product manufacturing
Business sector, Iron and steel mills and ferro-alloy manufacturing
Business sector, Steel product manufacturing from purchased steel
Business sector, Alumina and aluminum production and processing
Business sector, Non-ferrous metal (except aluminum) production and processing
Business sector, Foundries
Business sector, Forging and stamping

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Business sector, Cutlery, hand tools and other fabricated metal product manufacturing
Business sector, Architectural and structural metals manufacturing
Business sector, Boiler, tank and shipping container manufacturing
Business sector, Hardware manufacturing
Business sector, Spring and wire product manufacturing
Business sector, Machine shops, turned product, and screw, nut and bolt manufacturing
Business sector, Coating, engraving, heat treating and allied activities
Business sector, Agricultural, construction and mining machinery manufacturing
Business sector, Industrial machinery manufacturing
Business sector, Commercial and service industry machinery manufacturing
Business sector, Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing
Business sector, Metalworking machinery manufacturing
Business sector, Engine, turbine and power transmission equipment manufacturing
Business sector, Other general-purpose machinery manufacturing
Business sector, Computer and peripheral equipment manufacturing
Business sector, Communications equipment manufacturing
Business sector, Other electronic product manufacturing
Business sector, Semiconductor and other electronic component manufacturing
Business sector, Electric lighting equipment manufacturing
Business sector, Household appliance manufacturing
Business sector, Electrical equipment manufacturing
Business sector, Other electrical equipment and component manufacturing
Business sector, Automobile and light-duty motor vehicle manufacturing
Business sector, Heavy-duty truck manufacturing
Business sector, Motor vehicle body and trailer manufacturing
Business sector, Motor vehicle gasoline engine and engine parts manufacturing
Business sector, Motor vehicle electrical and electronic equipment manufacturing
Business sector, Motor vehicle steering and suspension components (except spring) manufacturing
Business sector, Motor vehicle brake system manufacturing
Business sector, Motor vehicle transmission and power train parts manufacturing
Business sector, Motor vehicle seating and interior trim manufacturing
Business sector, Motor vehicle metal stamping
Business sector, Other motor vehicle parts manufacturing

	Business sector, Aerospace product and parts manufacturing
	Business sector, Railroad rolling stock manufacturing
	Business sector, Ship and boat building
	Business sector, Other transportation equipment manufacturing
	Business sector, Household and institutional furniture and kitchen cabinet manufacturing
	Business sector, Office furniture (including fixtures) manufacturing
	Business sector, Other furniture-related product manufacturing
	Business sector, Medical equipment and supplies manufacturing
	Business sector, Other miscellaneous manufacturing
<b>Wholesale trade</b>	Business sector, Farm product wholesaler-distributors
	Business sector, Petroleum product wholesaler-distributors
	Business sector, Food, beverage and tobacco wholesaler-distributors
	Business sector, Personal and household goods wholesaler-distributors
	Business sector, Motor vehicle and parts wholesaler-distributors
	Business sector, Building material and supplies wholesaler-distributors
	Business sector, Machinery, equipment and supplies wholesaler-distributors
	Business sector, Miscellaneous wholesaler-distributors
	Business sector, Wholesale electronic markets, and agents and brokers
<b>Retail trade</b>	Business sector, Motor vehicle and parts dealers
	Business sector, Furniture and home furnishings stores
	Business sector, Electronics and appliance stores
	Business sector, Building material and garden equipment and supplies dealers
	Business sector, Food and beverage stores
	Business sector, Health and personal care stores
	Business sector, Gasoline stations
	Business sector, Clothing and clothing accessories stores
	Business sector, Sporting goods, hobby, book and music stores
	Business sector, General merchandise stores
	Business sector, Miscellaneous store retailers
	Business sector, Non-store retailers
<b>Transportation and warehousing</b>	Business sector, Air transportation
	Business sector, Rail transportation
	Business sector, Water transportation
	Business sector, Truck transportation
	Business sector, Urban transit systems
	Business sector, Other transit and ground passenger transportation and scenic and sightseeing transportation
	Business sector, Taxi and limousine service
	Business sector, Crude oil and other pipeline transportation

	Business sector, Pipeline transportation of natural gas
	Business sector, Support activities for transportation
<b>Information and cultural industries</b>	Business sector, Postal service
	Business sector, Couriers and messengers
	Business sector, Warehousing and storage
	Business sector, Newspaper publishers
	Business sector, Periodical, book and directory publishers
	Business sector, Software publishers
	Business sector, Motion picture and video industries (except exhibition)
	Business sector, Motion picture and video exhibition
	Business sector, Sound recording industries
	Business sector, Radio and television broadcasting
	Business sector, Pay and specialty television
	Business sector, Telecommunications
	Business sector, Data processing, hosting, and related services
	Business sector, Other information services
<b>Finance, insurance, real estate, rental and leasing and holding companies</b>	Business sector, Monetary authorities - central bank
	Business sector, Banking and other depository credit intermediation
	Business sector, Local credit unions
	Business sector, Non-depository credit intermediation
	Business sector, Activities related to credit intermediation
	Business sector, Financial investment services, funds and other financial vehicles
	Business sector, Insurance carriers
	Business sector, Agencies, brokerages and other insurance related activities
	Business sector, Lessors of real estate
	Business sector, Offices of real estate agents and brokers and activities related to real estate
<b>Owner occupied dwellings</b>	Business sector, Owner-occupied dwellings
	Business sector, Automotive equipment rental and leasing
	Business sector, Rental and leasing services (except automotive equipment)
	Business sector, Lessors of non-financial intangible assets (except copyrighted works)
<b>Professional, scientific and technical services</b>	Business sector, Legal services
	Business sector, Accounting, tax preparation, bookkeeping and payroll services
	Business sector, Architectural, engineering and related services
	Business sector, Specialized design services
	Business sector, Computer systems design and related services
	Business sector, Management, scientific and technical consulting services



	Business sector, Scientific research and development services
	Business sector, Advertising, public relations, and related services
	Business sector, Other professional, scientific and technical services
<b>Administrative and support, waste management and remediation services</b>	Business sector, Holding companies
	Business sector, Office administrative services
	Business sector, Facilities and other support services
	Business sector, Employment services
	Business sector, Business support services
	Business sector, Travel arrangement and reservation services
	Business sector, Investigation and security services
	Business sector, Services to buildings and dwellings
	Business sector, Waste management and remediation services
<b>Educational services</b>	Business sector, Educational services
<b>Health care and social assistance</b>	Business sector, Offices of physicians
	Business sector, Offices of dentists
	Business sector, Miscellaneous ambulatory health care services
	Business sector, Nursing and residential care facilities
	Business sector, Social assistance
<b>Arts, entertainment and recreation</b>	Business sector, Performing arts, spectator sports and related industries, and heritage institutions
	Business sector, Amusement and recreation industries
	Business sector, Gambling industries
	Business sector, Traveller accommodation
	Business sector, RV (recreational vehicle) parks, recreational camps, and rooming and boarding houses
<b>Accommodation and food services</b>	Business sector, Food services and drinking places
<b>Other services (except public administration)</b>	Business sector, Automotive repair and maintenance
	Business sector, Repair and maintenance (except automotive)
	Business sector, Personal care services and other personal services
	Business sector, Funeral services
	Business sector, Dry cleaning and laundry services
	Business sector, Professional and similar organizations
	Business sector, Private households
<b>Non-profit institutions serving households</b>	Non-profit sector, Educational services
	Non-profit sector, Ambulatory health care services
	Non-profit sector, Social assistance
	Non-profit sector, Arts, entertainment and recreation
	Non-profit sector, Religious organizations
	Non-profit sector, Grant-making, civic, and professional and similar organizations

	Non-profit sector, Other non-profit institutions serving households
<b>Government education services</b>	Government sector, Elementary and secondary schools
	Government sector, Community colleges and C.E.G.E.P.s
	Government sector, Universities
	Government sector, Other educational services
<b>Government health services</b>	Government sector, Hospitals
	Government sector, Nursing and residential care facilities
	Government sector, Defence services
<b>Other federal government services</b>	Government sector, Other federal government services (except defence)
<b>Other provincial and territorial government services</b>	Government sector, Other provincial and territorial government services
<b>Other municipal government services</b>	Government sector, Other municipal government services
<b>Other aboriginal government services</b>	Government sector, Other aboriginal government services

**Table A3 – Final demand (consumption expenditure) labels**

<b>Final consumption expenditure summary level</b>	<b>Final consumption expenditure detailed level</b>
<b>Household final consumption expenditure</b>	Final consumption expenditure, Food
	Final consumption expenditure, Non-alcoholic beverages
	Final consumption expenditure, Alcoholic beverages
	Final consumption expenditure, Tobacco
	Final consumption expenditure, Garments
	Final consumption expenditure, Cleaning of clothing
	Final consumption expenditure, Clothing materials, other articles of clothing and clothing accessories
	Final consumption expenditure, Footwear
	Final consumption expenditure, Paid rental fees for housing
	Final consumption expenditure, Imputed rental fees for housing
	Final consumption expenditure, Materials for the maintenance and repair of the dwelling
	Final consumption expenditure, Services for the maintenance and repair of the dwelling
	Final consumption expenditure, Electricity
	Final consumption expenditure, Gas
	Final consumption expenditure, Other fuels
	Final consumption expenditure, Water supply and sanitation services
	Final consumption expenditure, Furniture and furnishings
	Final consumption expenditure, Carpets and other floor coverings
	Final consumption expenditure, Household textiles
	Final consumption expenditure, Major household appliances
	Final consumption expenditure, Small electric household appliances
	Final consumption expenditure, Major tools and equipment
	Final consumption expenditure, Small tools and miscellaneous accessories
	Final consumption expenditure, Other semi-durable household goods
	Final consumption expenditure, Other non-durable household goods
	Final consumption expenditure, Repair of personal and household goods except vehicles
	Final consumption expenditure, Renting and leasing of personal and household goods except passenger vehicles
	Final consumption expenditure, Other services related to the dwelling and property
	Final consumption expenditure, Therapeutic appliances and equipment
	Final consumption expenditure, Pharmaceutical products and other medical products
	Final consumption expenditure, Out-patient services
Final consumption expenditure, Hospital services	
Final consumption expenditure, New passenger cars	

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Final consumption expenditure, New trucks, vans and sport utility vehicles

Final consumption expenditure, Used motor vehicles

Final consumption expenditure, Other vehicles

Final consumption expenditure, Spare parts and accessories for vehicles

Final consumption expenditure, Fuels and lubricants

Final consumption expenditure, Maintenance and repair of vehicles

Final consumption expenditure, Parking

Final consumption expenditure, Passenger vehicle renting

Final consumption expenditure, Other services related to the operation of transport equipment

Final consumption expenditure, Railway transport

Final consumption expenditure, Urban transit

Final consumption expenditure, Interurban bus

Final consumption expenditure, Taxi and limousine

Final consumption expenditure, Air transport

Final consumption expenditure, Water transport

Final consumption expenditure, Other transport services

Final consumption expenditure, Postal services

Final consumption expenditure, Telecommunication equipment

Final consumption expenditure, Telecommunication services

Final consumption expenditure, Information processing equipment

Final consumption expenditure, Recording media

Final consumption expenditure, Audio-visual and photographic equipment

Final consumption expenditure, Major durables for outdoor recreation

Final consumption expenditure, Musical instruments and major durables for indoor recreation

Final consumption expenditure, Games, toys and hobbies

Final consumption expenditure, Equipment for sport, camping and open-air recreation

Final consumption expenditure, Garden products, plants and flowers

Final consumption expenditure, Veterinary and other services for pets

Final consumption expenditure, Pets and pet food

Final consumption expenditure, Recreational and sporting services

Final consumption expenditure, Cable, satellite and other program distribution services

Final consumption expenditure, Cinemas

Final consumption expenditure, Photographic services

Final consumption expenditure, Other cultural services

Final consumption expenditure, Games of chance

Final consumption expenditure, Books

Final consumption expenditure, Newspapers and periodicals

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	Final consumption expenditure, Miscellaneous printed matter and stationery and drawing materials
	Final consumption expenditure, University education
	Final consumption expenditure, Other education
	Final consumption expenditure, Food and non-alcoholic beverage services
	Final consumption expenditure, Alcoholic beverage services
	Final consumption expenditure, Accommodation services
	Final consumption expenditure, Life insurance
	Final consumption expenditure, Health insurance
	Final consumption expenditure, Insurance related to transport
	Final consumption expenditure, Property insurance
	Final consumption expenditure, Implicit loan charges
	Final consumption expenditure, Implicit deposit charges
	Final consumption expenditure, Stock and bond commissions
	Final consumption expenditure, Other actual financial charges
	Final consumption expenditure, Trusteed pension funds
	Final consumption expenditure, Mutual funds
	Final consumption expenditure, Personal grooming services
	Final consumption expenditure, Electrical appliances for personal care
	Final consumption expenditure, Other appliances, articles and products for personal care
	Final consumption expenditure, Jewellery, clocks and watches
	Final consumption expenditure, Other personal effects
	Final consumption expenditure, Child care services outside the home
	Final consumption expenditure, Child care services in the home
	Final consumption expenditure, Other social services
	Final consumption expenditure, Undertaking and other funeral services
	Final consumption expenditure, Legal and other services
<b>Expenditure by Canadians abroad</b>	Final consumption expenditure, Expenditure by Canadians abroad
<b>Expenditure by Canadians in other provinces or territories</b>	Final consumption expenditure, Expenditure by Canadians in other provinces or territories
<b>Expenditure by non-residents in Canada</b>	Final consumption expenditure, Expenditure by non-residents in Canada
<b>Expenditure by Canadians residing in other provinces or territories</b>	Final consumption expenditure, Expenditure by Canadians residing in other provinces or territories
<b>Non-profit institutions serving households' final consumption expenditure</b>	Final consumption expenditure, Non-profit institutions serving households' final consumption expenditure
	Final consumption expenditure, Educational services
	Final consumption expenditure, Hospitals
	Final consumption expenditure, Nursing and residential care facilities
	Final consumption expenditure, Defence services
<b>Governments final consumption expenditure</b>	Final consumption expenditure, Other federal government services (except defence)

Final consumption expenditure, Other provincial and territorial government services

Final consumption expenditure, Other municipal government services

Final consumption expenditure, Other aboriginal government services

**Table A4 – Final demand (gross fixed capital formation) labels**

Gross fixed capital formation summary level	Gross fixed capital formation detailed level
	<b>CONSTRUCTION</b>
<b>Construction, residential structures</b>	Construction, Residential structures
<b>Construction, business, non-residential structures</b>	Construction, Business, Crop production
	Construction, Business, Animal production
	Construction, Business, Forestry and logging
	Construction, Business, Fishing, hunting and trapping
	Construction, Business, Support activities for agriculture and forestry
	Construction, Business, Conventional oil and gas extraction
	Construction, Business, Mining and quarrying (except oil and gas)
	Construction, Business, Support activities for mining and oil and gas extraction
	Construction, Business, Utilities
	Construction, Business, Construction
	Construction, Business, Food manufacturing
	Construction, Business, Beverage and tobacco product manufacturing
	Construction, Business, Textile and textile product mills
	Construction, Business, Clothing and leather and allied product manufacturing
	Construction, Business, Wood product manufacturing
	Construction, Business, Paper manufacturing
	Construction, Business, Printing and related support activities
	Construction, Business, Petroleum and coal product manufacturing
	Construction, Business, Chemical manufacturing
	Construction, Business, Plastics and rubber products manufacturing
	Construction, Business, Non-metallic mineral product manufacturing
	Construction, Business, Primary metal manufacturing
	Construction, Business, Fabricated metal product manufacturing
	Construction, Business, Machinery manufacturing
	Construction, Business, Computer and electronic product manufacturing
	Construction, Business, Electrical equipment, appliance and component manufacturing
	Construction, Business, Transportation equipment manufacturing
	Construction, Business, Furniture and related product manufacturing
	Construction, Business, Miscellaneous manufacturing
	Construction, Business, Wholesale trade

	Construction, Business, Retail trade
	Construction, Business, Transportation and warehousing
	Construction, Business, Information and cultural industries
	Construction, Business, Finance and insurance
	Construction, Business, Real estate and rental and leasing
	Construction, Business, Professional, scientific and technical services
	Construction, Business, Holding companies
	Construction, Business, Administrative and support, waste management and remediation services
	Construction, Business, Educational services
	Construction, Business, Health care and social assistance
	Construction, Business, Arts, entertainment and recreation
	Construction, Business, Accommodation and food services
	Construction, Business, Other services
<b>Construction, non-profit institutions serving households</b>	Construction, Non-profit institutions serving households
<b>Construction, governments</b>	Construction, Government, Educational services
	Construction, Government, Hospitals
	Construction, Government, Nursing and residential care facilities
	Construction, Government, Defence services
	Construction, Government, Other federal government services (except defence)
	Construction, Government, Other provincial and territorial government services
	Construction, Government, Other municipal government services
	Construction, Government, Other aboriginal government services
<b>MACHINE AND EQUIPMENT</b>	
<b>Machinery and equipment, business</b>	Machinery and equipment, Business, Crop production
	Machinery and equipment, Business, Animal production
	Machinery and equipment, Business, Forestry and logging
	Machinery and equipment, Business, Fishing, hunting and trapping
	Machinery and equipment, Business, Support activities for agriculture and forestry
	Machinery and equipment, Business, Conventional oil and gas extraction
	Machinery and equipment, Business, Mining and quarrying (except oil and gas)
	Machinery and equipment, Business, Support activities for mining and oil and gas extraction
	Machinery and equipment, Business, Utilities
	Machinery and equipment, Business, Construction
	Machinery and equipment, Business, Food manufacturing
	Machinery and equipment, Business, Beverage and tobacco product manufacturing

	Machinery and equipment, Business, Textile and textile product mills
	Machinery and equipment, Business, Clothing and leather and allied product manufacturing
	Machinery and equipment, Business, Wood product manufacturing
	Machinery and equipment, Business, Paper manufacturing
	Machinery and equipment, Business, Printing and related support activities
	Machinery and equipment, Business, Petroleum and coal product manufacturing
	Machinery and equipment, Business, Chemical manufacturing
	Machinery and equipment, Business, Plastics and rubber products manufacturing
	Machinery and equipment, Business, Non-metallic mineral product manufacturing
	Machinery and equipment, Business, Primary metal manufacturing
	Machinery and equipment, Business, Fabricated metal product manufacturing
	Machinery and equipment, Business, Machinery manufacturing
	Machinery and equipment, Business, Computer and electronic product manufacturing
	Machinery and equipment, Business, Electrical equipment, appliance and component manufacturing
	Machinery and equipment, Business, Transportation equipment manufacturing
	Machinery and equipment, Business, Furniture and related product manufacturing
	Machinery and equipment, Business, Miscellaneous manufacturing
	Machinery and equipment, Business, Wholesale trade
	Machinery and equipment, Business, Retail trade
	Machinery and equipment, Business, Transportation and warehousing
	Machinery and equipment, Business, Information and cultural industries
	Machinery and equipment, Business, Finance and insurance
	Machinery and equipment, Business, Real estate and rental and leasing
	Machinery and equipment, Business, Professional, scientific and technical services
	Machinery and equipment, Business, Holding companies
	Machinery and equipment, Business, Administrative and support, waste management and remediation services
	Machinery and equipment, Business, Educational services
	Machinery and equipment, Business, Health care and social assistance
	Machinery and equipment, Business, Arts, entertainment and recreation
	Machinery and equipment, Business, Accommodation and food services
	Machinery and equipment, Business, Other services
<b>Machinery and equipment, used cars and equipment and scrap</b>	Machinery and equipment, Used cars and equipment and scrap
<b>Machinery and equipment, non-profit institutions serving households</b>	Machinery and equipment, Non-profit institutions serving households



<b>Machinery and equipment, governments</b>	Machinery and equipment, Government, Educational services
	Machinery and equipment, Government, Hospitals
	Machinery and equipment, Government, Nursing and residential care facilities
	Machinery and equipment, Government, Defence services
	Machinery and equipment, Government, Other federal government services (except defence)
	Machinery and equipment, Government, Other provincial and territorial government services
	Machinery and equipment, Government, Other municipal government services
	Machinery and equipment, Government, Other aboriginal government services
<b>INTELLECTUAL PROPERTY</b>	
<b>Intellectual property products, business</b>	Intellectual property products, Business, Crop production
	Intellectual property products, Business, Animal production
	Intellectual property products, Business, Forestry and logging
	Intellectual property products, Business, Fishing, hunting and trapping
	Intellectual property products, Business, Support activities for agriculture and forestry
	Intellectual property products, Business, Conventional oil and gas extraction
	Intellectual property products, Business, Mining and quarrying (except oil and gas)
	Intellectual property products, Business, Support activities for mining and oil and gas extraction
	Intellectual property products, Business, Utilities
	Intellectual property products, Business, Construction
	Intellectual property products, Business, Food manufacturing
	Intellectual property products, Business, Beverage and tobacco product manufacturing
	Intellectual property products, Business, Textile and textile product mills
	Intellectual property products, Business, Clothing and leather and allied product manufacturing
	Intellectual property products, Business, Wood product manufacturing
	Intellectual property products, Business, Paper manufacturing
	Intellectual property products, Business, Printing and related support activities
Intellectual property products, Business, Petroleum and coal product manufacturing	
Intellectual property products, Business, Chemical manufacturing	
Intellectual property products, Business, Plastics and rubber products manufacturing	
Intellectual property products, Business, Non-metallic mineral product manufacturing	
Intellectual property products, Business, Primary metal manufacturing	

	Intellectual property products, Business, Fabricated metal product manufacturing
	Intellectual property products, Business, Machinery manufacturing
	Intellectual property products, Business, Computer and electronic product manufacturing
	Intellectual property products, Business, Electrical equipment, appliance and component manufacturing
	Intellectual property products, Business, Transportation equipment manufacturing
	Intellectual property products, Business, Furniture and related product manufacturing
	Intellectual property products, Business, Miscellaneous manufacturing
	Intellectual property products, Business, Wholesale trade
	Intellectual property products, Business, Retail trade
	Intellectual property products, Business, Transportation and warehousing
	Intellectual property products, Business, Information and cultural industries
	Intellectual property products, Business, Finance and insurance
	Intellectual property products, Business, Real estate and rental and leasing
	Intellectual property products, Business, Professional, scientific and technical services
	Intellectual property products, Business, Holding companies
	Intellectual property products, Business, Administrative and support, waste management and remediation services
	Intellectual property products, Business, Educational services
	Intellectual property products, Business, Health care and social assistance
	Intellectual property products, Business, Arts, entertainment and recreation
	Intellectual property products, Business, Accommodation and food services
	Intellectual property products, Business, Other services
<b>Intellectual property products, non-profit institutions serving households</b>	Intellectual property products, Non-profit institutions serving households
<b>Intellectual property products, governments</b>	Intellectual property products, Government, Educational services
	Intellectual property products, Government, Hospitals
	Intellectual property products, Government, Nursing and residential care facilities
	Intellectual property products, Government, Defence services
	Intellectual property products, Government, Other federal government services (except defence)
	Intellectual property products, Government, Other provincial and territorial government services
	Intellectual property products, Government, Other municipal government services
	Intellectual property products, Government, Other aboriginal government services

Table A5 – Exports, value-added, and imports labels

Exports at detailed and summary level
Interprovincial exports, Newfoundland and Labrador
Interprovincial exports, Prince Edward Island
Interprovincial exports, Nova Scotia
Interprovincial exports, New Brunswick
Interprovincial exports, Quebec
Interprovincial exports, Manitoba
Interprovincial exports, Saskatchewan
Interprovincial exports, Alberta
Interprovincial exports, British Columbia
Interprovincial exports, Yukon
Interprovincial exports, Northwest Territories
Interprovincial exports, Nunavut
Interprovincial exports, Canadian territorial enclaves abroad
Gross Value Added at detailed and summary level
Taxes on products
Subsidies on products
Subsidies on production
Taxes on production
Wages and salaries
Employers' social contributions
Gross mixed income
Gross operating surplus
Imports at detailed and summary level
International imports
Interprovincial imports, Newfoundland and Labrador
Interprovincial imports, Prince Edward Island
Interprovincial imports, Nova Scotia
Interprovincial imports, New Brunswick
Interprovincial imports, Quebec
Interprovincial imports, Manitoba
Interprovincial imports, Saskatchewan
Interprovincial imports, Alberta
Interprovincial imports, British Columbia
Interprovincial imports, Yukon
Interprovincial imports, Northwest Territories
Interprovincial imports, Nunavut
Interprovincial imports, Canadian territorial enclaves abroad

**Table B1 – Concordance of industries in regional economic data and summary level**

<b>Industries in regional economic data</b>	<b>Summary level industries in IO model</b>
<b>Agriculture</b>	Crop and animal production
<b>Forestry, fishing, mining, quarrying, oil and gas</b>	Forestry and logging
	Fishing, hunting and trapping
	Support activities for agriculture and forestry
	Mining, quarrying, and oil and gas extraction
<b>Utilities</b>	Utilities
<b>Construction</b>	Residential building construction
	Non-residential building construction
	Engineering construction
	Repair construction
	Other activities of the construction industry
<b>Manufacturing</b>	Manufacturing
<b>Wholesale and retail trade</b>	Wholesale trade
	Retail trade
<b>Transportation and warehousing</b>	Transportation and warehousing
<b>Information, culture and recreation</b>	Information and cultural industries
<b>Finance, insurance, real estate, rental and leasing</b>	Finance, insurance, real estate, rental and leasing and holding companies
	Owner occupied dwellings
<b>Professional, scientific and technical services</b>	Professional, scientific and technical services
<b>Business, building and other support services</b>	Administrative and support, waste management and remediation services
<b>Educational services</b>	Educational services
<b>Health care and social assistance</b>	Health care and social assistance
	Arts, entertainment and recreation
<b>Accommodation and food services</b>	Accommodation and food services
<b>Other services (except public administration)</b>	Other services (except public administration)
<b>Public administration</b>	Non-profit institutions serving households
	Government education services
	Government health services
	Other federal government services
	Other provincial and territorial government services
	Other municipal government services
	Other aboriginal government services

Table B2 – Employment data by metropolitan area

Industries in regional economic data	Ottawa-Gatineau	Kingston	Peterborough	Oshawa	Toronto	Hamilton	St.		RoW	Brantford	Guelph	London	Windsor	Barrie	Greater Sudbury	Thunder Bay	ON
							Catharines-Niagara										
Agriculture	1.7	x	x	x	7.8	3.1	4	2.5	x	x	3.5	x	x	x	x	81.8	
Forestry, fishing, mining, quarrying, oil and gas	x	x	x	x	5.9	x	x	x	x	x	0	x	x	6.8	x	33.2	
Utilities	1.6	x	x	5.5	13.9	1.6	1.9	x	x	x	x	x	x	x	x	51.1	
Construction	19.6	5.2	5.1	18.5	186.1	27.9	15.3	20.2	4.9	4	16.4	8.2	10.2	5.1	4.2	467.3	
Manufacturing	17.5	3.8	4.2	19.7	323.9	46.8	20.8	54.5	12.7	15.9	27.1	32.9	11.4	3	2.3	748.6	
Wholesale and retail trade	69	11.5	10.6	33.3	464.8	62.4	31.1	40.3	10.2	11.2	37.2	22.1	20.1	14.3	9.8	1047	
Transportation and warehousing	14.8	2.8	2.4	10.7	152.5	19	8.1	14.1	3.7	2.9	11.8	8.3	5.1	4	3.3	329	
Finance, insurance, real estate, rental and leasing	25.6	3.7	2.9	13.7	326	21.9	10.1	21.1	3.5	4.2	16.4	6.1	6.8	3.2	2.7	512.1	
Professional, scientific and technical services	60.5	3.9	2.7	11.7	332.4	29.3	9.1	20.7	1.9	6	12.6	6.7	6.4	3.9	3.1	559.9	
Business, building and other support services	21.4	3.3	3.1	9.6	158.9	19.3	11.1	11.8	4.5	3.6	12	5	6.6	3.5	2.7	334.7	
Educational services	40.4	10.6	4.5	15.9	211.5	29.5	13.7	23.8	4.4	8.7	22.5	12.5	6.6	7.2	4.8	494.6	
Health care and social assistance	65.7	13.6	10.7	21.1	312.3	47.5	23.3	26.1	8.6	9.1	36.7	20.8	12.5	12.8	11.4	798.2	
Information, culture and recreation	27.2	3.6	2.1	9.4	167.9	17.8	8.4	10.2	2.2	2.8	10	7.3	5.1	3.2	2.4	316.5	
Accommodation and food services	35.8	6.6	4.9	9.3	191.3	25	23	18.6	4.8	5.9	17.4	11.8	7.4	6.9	5.1	450.3	
Other services (except public administration)	23.6	3.6	2.5	8.3	128.6	15	6.8	8.9	2.9	2.7	8.2	6.7	4.9	3.1	2.8	286.8	
Public administration	108.6	7.6	3.5	13.4	103.6	17	8.4	8.2	2.3	3.7	9.9	4.5	6.4	5.7	4.5	366.8	

**Table B3 – Employment data for regions of interests**

<b>Industries in regional economic data</b>	<b>RoW</b>		<b>ON</b>		<b>Rest of ON</b>	
<b>SUIC</b>	Employment x 1000	Employment proportion	Employment x 1000	Employment proportion	Employment x 1000	Employment proportion
<b>Agriculture</b>	2.5	0.03056	81.8	1	79.3	0.96944
<b>Forestry, fishing, mining, quarrying, oil and gas</b>	1.3	0.03922	33.2	1	31.9	0.96078
<b>Utilities</b>	2.0	0.03922	51.1	1	49.1	0.96078
<b>Construction</b>	20.2	0.04323	467.3	1	447.1	0.95677
<b>Manufacturing</b>	54.5	0.07280	748.6	1	694.1	0.92720
<b>Wholesale and retail trade</b>	40.3	0.03849	1047	1	1006.7	0.96151
<b>Transportation and warehousing</b>	14.1	0.04286	329	1	314.9	0.95714
<b>Finance, insurance, real estate, rental and leasing</b>	21.1	0.04120	512.1	1	491	0.95880
<b>Professional, scientific and technical services</b>	20.7	0.03697	559.9	1	539.2	0.96303
<b>Business, building and other support services</b>	11.8	0.03526	334.7	1	322.9	0.96474
<b>Educational services</b>	23.8	0.04812	494.6	1	470.8	0.95188
<b>Health care and social assistance</b>	26.1	0.03270	798.2	1	772.1	0.96730
<b>Information, culture and recreation</b>	10.2	0.03223	316.5	1	306.3	0.96777
<b>Accommodation and food services</b>	18.6	0.04131	450.3	1	431.7	0.95869
<b>Other services (except public administration)</b>	8.9	0.03103	286.8	1	277.9	0.96897
<b>Public administration</b>	8.2	0.02236	366.8	1	358.6	0.97764

## Appendix C – Concordance of Energy use and detailed IO industry classification

Table C1 – Energy intensities for detailed IO industry classification

Energy Use sector	Detailed industry	Energy (TJ)	Gross output (\$)	Energy intensity (TJ/\$)
<b>Crop and animal production [BS11A00]</b>	Crop production (except greenhouse, nursery and floriculture production)	2.89E+05	3.04E+07	4.67E-03
	Greenhouse, nursery and floriculture production		3.64E+06	
	Animal production (except aquaculture)		2.69E+07	
	Aquaculture		8.94E+05	
<b>Forestry and logging [BS11300]</b>	Forestry and logging	2.76E+04	1.02E+07	2.71E-03
<b>Fishing, hunting and trapping [BS11400]</b>	Fishing, hunting and trapping	8.64E+03	2.90E+06	2.98E-03
<b>Support activities for agriculture and forestry [BS11500]</b>	Support activities for crop and animal production	9.24E+03	1.06E+06	3.02E-03
	Support activities for forestry		2.01E+06	
<b>Oil and gas extraction [BS21100]</b>	Conventional oil and gas extraction	1.70E+06	9.23E+07	1.01E-02
	Non-conventional oil extraction		7.62E+07	
<b>Coal mining [BS21210]</b>	Coal mining	1.84E+04	3.91E+06	4.71E-03
<b>Metal ore mining [BS21220]</b>	Gold and silver ore mining	1.09E+05	6.50E+06	4.69E-03
	Copper, nickel, lead and zinc ore mining		1.08E+07	
	Other metal ore mining		1.80E+06	
	Iron ore mining		4.21E+06	
<b>Non-metallic mineral mining and quarrying [BS21230]</b>	Stone mining and quarrying	5.46E+04	1.74E+06	4.17E-03
	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying		1.82E+06	
	Diamond mining		2.24E+06	
	Other non-metallic mineral mining and quarrying (except diamond and potash)		1.34E+06	
	Potash mining		5.94E+06	
<b>Support activities for mining and oil and gas extraction [BS21300]</b>	Support activities for oil and gas extraction	1.14E+05	2.80E+07	3.38E-03
	Support activities for mining		5.74E+06	
<b>Electric power generation, transmission and distribution [BS22110]</b>	Electric power generation, transmission and distribution	1.31E+06	4.50E+07	2.90E-02

<b>Natural gas distribution, water, sewage and other systems [BS221A0]</b>	Natural gas distribution	2.14E+04	6.07E+06	3.19E-03
	Water, sewage and other systems		6.25E+05	
<b>Residential building construction [BS23A00]</b>	Residential building construction	2.45E+04	1.03E+08	2.38E-04
<b>Non-residential building construction [BS23B00]</b>	Non-residential building construction	6.86E+03	4.81E+07	1.43E-04
<b>Transportation engineering construction [BS23C10]</b>	Transportation engineering construction	1.17E+04	2.20E+07	5.33E-04
<b>Oil and gas engineering construction [BS23C20]</b>	Oil and gas engineering construction	1.82E+04	7.98E+07	2.28E-04
<b>Electric power engineering construction [BS23C30]</b>	Electric power engineering construction	1.19E+04	2.00E+07	5.97E-04
<b>Communication engineering construction [BS23C40]</b>	Communication engineering construction	4.49E+03	4.90E+06	9.16E-04
<b>Other engineering construction [BS23C50]</b>	Other engineering construction	1.41E+04	2.22E+07	6.38E-04
<b>Repair construction [BS23D00]</b>	Repair construction	8.46E+03	4.05E+07	2.09E-04
<b>Other activities of the construction industry [BS23E00]</b>	Other activities of the construction industry	1.03E+04	4.09E+06	2.52E-03
<b>Animal food manufacturing [BS31110]</b>	Animal food manufacturing	1.00E+04	8.24E+06	1.22E-03
<b>Sugar and confectionery product manufacturing [BS31130]</b>	Sugar and confectionery product manufacturing	1.03E+04	4.46E+06	2.31E-03
<b>Fruit and vegetable preserving and specialty food manufacturing [BS31140]</b>	Fruit and vegetable preserving and specialty food manufacturing	1.23E+04	7.08E+06	1.73E-03
<b>Dairy product manufacturing [BS31150]</b>	Dairy product manufacturing	9.12E+03	1.38E+07	6.61E-04
<b>Meat product manufacturing [BS31160]</b>	Meat product manufacturing	2.55E+04	2.65E+07	9.60E-04
<b>Seafood product preparation and packaging [BS31170]</b>	Seafood product preparation and packaging	4.20E+03	4.85E+06	8.67E-04
<b>Miscellaneous food manufacturing [BS311A0]</b>	Grain and oilseed milling	5.36E+04	1.12E+07	1.83E-03
	Bakeries and tortilla manufacturing		8.99E+06	
	Other food manufacturing		9.12E+06	
<b>Soft drink and ice manufacturing [BS31211]</b>	Soft drink and ice manufacturing	4.37E+03	4.43E+06	9.87E-04
<b>Breweries [BS31212]</b>	Breweries	1.00E+04	5.76E+06	1.74E-03
<b>Wineries and distilleries [BS3121A]</b>	Wineries and distilleries	6.07E+03	2.21E+06	2.75E-03



<b>Tobacco manufacturing [BS31220]</b>	Tobacco manufacturing	6.23E+0 2	1.83E+06	3.41E-04
<b>Textile and textile product mills [BS31A00]</b>	Textile and textile product mills	5.83E+0 3	3.25E+06	1.79E-03
<b>Clothing and leather and allied product manufacturing [BS31B00]</b>	Clothing and leather and allied product manufacturing	1.72E+0 3	2.98E+06	5.77E-04
<b>Wood product manufacturing [BS32100]</b>	Sawmills and wood preservation	1.55E+0 5	1.43E+07	5.63E-03
	Veneer, plywood and engineered wood product manufacturing		5.71E+06	
	Other wood product manufacturing		7.57E+06	
<b>Pulp, paper and paperboard mills [BS32210]</b>	Pulp, paper and paperboard mills	6.23E+0 5	1.69E+07	3.69E-02
<b>Converted paper product manufacturing [BS32220]</b>	Converted paper product manufacturing	1.95E+0 4	9.40E+06	2.08E-03
<b>Printing and related support activities [BS32300]</b>	Printing and related support activities	8.82E+0 3	9.13E+06	9.66E-04
<b>Petroleum and coal product manufacturing [BS32400]</b>	Petroleum refineries	3.69E+0 5	7.50E+07	4.56E-03
	Petroleum and coal product manufacturing (except petroleum refineries)		5.95E+06	
<b>Basic chemical manufacturing [BS32510]</b>	Basic chemical manufacturing	0.00E+0 0	1.74E+07	0.00E+00
	Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing		9.72E+06	
<b>Pesticide, fertilizer and other agricultural chemical manufacturing [BS32530]</b>	Pesticide, fertilizer and other agricultural chemical manufacturing	6.98E+0 4	5.47E+06	1.28E-02
<b>Pharmaceutical and medicine manufacturing [BS32540]</b>	Pharmaceutical and medicine manufacturing	7.01E+0 3	1.21E+07	5.78E-04
<b>Miscellaneous chemical product manufacturing [BS325C0] 9</b>	Paint, coating and adhesive manufacturing	0.00E+0 0	2.99E+06	0.00E+00
	Soap, cleaning compound and toilet preparation manufacturing		3.45E+06	
	Other chemical product manufacturing		5.37E+06	
<b>Plastic product manufacturing [BS32610]</b>	Plastic product manufacturing	2.83E+0 4	2.21E+07	1.28E-03
<b>Rubber product manufacturing [BS32620]</b>	Rubber product manufacturing	8.13E+0 3	5.39E+06	1.51E-03
<b>Non-metallic mineral product manufacturing (except cement and concrete products) [BS327A0]</b>	Non-metallic mineral product manufacturing (except cement and concrete products)	3.00E+0 4	5.85E+06	5.12E-03
<b>Cement and concrete product manufacturing [BS32730]</b>	Cement and concrete product manufacturing	7.38E+0 4	9.88E+06	7.47E-03

<b>Primary metal manufacturing [BS33100]</b>	Iron and steel mills and ferro-alloy manufacturing	4.80E+05	1.24E+07	7.12E-03
	Steel product manufacturing from purchased steel		6.28E+06	
	Alumina and aluminum production and processing		1.15E+07	
	Non-ferrous metal (except aluminum) production and processing		3.50E+07	
	Foundries		2.31E+06	
<b>Fabricated metal product manufacturing [BS33200]</b>	Forging and stamping	4.06E+04	1.51E+06	1.10E-03
	Cutlery, hand tools and other fabricated metal product manufacturing		5.91E+06	
	Architectural and structural metals manufacturing		1.49E+07	
	Boiler, tank and shipping container manufacturing		4.01E+06	
	Hardware manufacturing		1.31E+06	
	Spring and wire product manufacturing		8.89E+05	
	Machine shops, turned product, and screw, nut and bolt manufacturing		6.20E+06	
	Coating, engraving, heat treating and allied activities		2.21E+06	
<b>Machinery manufacturing [BS33300]</b>	Agricultural, construction and mining machinery manufacturing	2.35E+04	1.18E+07	6.11E-04
	Industrial machinery manufacturing		3.50E+06	
	Commercial and service industry machinery manufacturing		4.52E+06	
	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing		2.89E+06	
	Metalworking machinery manufacturing		4.00E+06	
	Engine, turbine and power transmission equipment manufacturing		2.95E+06	
	Other general-purpose machinery manufacturing		8.79E+06	
<b>Computer and peripheral equipment manufacturing [BS33410]</b>	Computer and peripheral equipment manufacturing	5.08E+02	1.66E+06	9.70E-05
	Communications equipment manufacturing		3.57E+06	
<b>Electronic product manufacturing [BS334B0]</b>	Other electronic product manufacturing	4.49E+03	6.05E+06	5.02E-04
	Semiconductor and other electronic component manufacturing		2.89E+06	
<b>Electrical equipment and component manufacturing [BS335A0]</b>	Electric lighting equipment manufacturing	5.23E+03	1.08E+06	5.81E-04

	Electrical equipment manufacturing		4.17E+06	
	Other electrical equipment and component manufacturing		3.76E+06	
<b>Household appliance manufacturing [BS33520]</b>	Household appliance manufacturing	3.27E+02	6.95E+05	4.71E-04
<b>Motor vehicle manufacturing [BS33610]</b>	Automobile and light-duty motor vehicle manufacturing	1.75E+04	5.65E+07	2.97E-04
	Heavy-duty truck manufacturing		2.40E+06	
<b>Motor vehicle body and trailer manufacturing [BS33620]</b>	Motor vehicle body and trailer manufacturing	2.52E+03	3.30E+06	7.63E-04
<b>Motor vehicle parts manufacturing [BS33630]</b>	Motor vehicle gasoline engine and engine parts manufacturing	1.62E+04	5.32E+06	5.85E-04
	Motor vehicle electrical and electronic equipment manufacturing		1.12E+06	
	Motor vehicle steering and suspension components (except spring) manufacturing		1.60E+06	
	Motor vehicle brake system manufacturing		4.33E+05	
	Motor vehicle transmission and power train parts manufacturing		4.19E+06	
	Motor vehicle seating and interior trim manufacturing		4.20E+06	
	Motor vehicle metal stamping		6.39E+06	
	Other motor vehicle parts manufacturing		4.39E+06	
<b>Aerospace product and parts manufacturing [BS33640]</b>	Aerospace product and parts manufacturing	8.91E+03	2.22E+07	4.01E-04
<b>Railroad rolling stock manufacturing [BS33650]</b>	Railroad rolling stock manufacturing	0.00E+00	1.41E+06	0.00E+00
<b>Ship and boat building [BS33660]</b>	Ship and boat building	8.07E+02	1.41E+06	5.73E-04
<b>Other transportation equipment manufacturing [BS33690]</b>	Other transportation equipment manufacturing	1.74E+03	5.26E+06	3.32E-04
<b>Furniture and related product manufacturing [BS33700]</b>	Household and institutional furniture and kitchen cabinet manufacturing	9.61E+03	5.98E+06	8.88E-04
	Office furniture (including fixtures) manufacturing		3.79E+06	
	Other furniture-related product manufacturing		1.05E+06	
<b>Miscellaneous manufacturing [BS33900]</b>	Medical equipment and supplies manufacturing	5.75E+03	3.14E+06	4.50E-04
	Other miscellaneous manufacturing		9.65E+06	
<b>Wholesale trade [BS41000]</b>	Farm product wholesaler-distributors	2.07E+05	3.71E+06	1.65E-02
	Petroleum product wholesaler-distributors		8.85E+06	
<b>Retail trade [BS4A000]</b>	Food, beverage and tobacco wholesaler-distributors	1.76E+05	2.08E+07	5.91E-04

	Personal and household goods wholesaler-distributors		2.68E+07	
	Motor vehicle and parts wholesaler-distributors		1.72E+07	
	Building material and supplies wholesaler-distributors		2.20E+07	
	Machinery, equipment and supplies wholesaler-distributors		3.74E+07	
	Miscellaneous wholesaler-distributors		1.93E+07	
	Wholesale electronic markets, and agents and brokers		4.70E+06	
	Motor vehicle and parts dealers		2.17E+07	
	Furniture and home furnishings stores		7.61E+06	
	Electronics and appliance stores		5.30E+06	
	Building material and garden equipment and supplies dealers		1.13E+07	
	Food and beverage stores		2.88E+07	
	Health and personal care stores		1.63E+07	
	Gasoline stations		9.78E+06	
	Clothing and clothing accessories stores		1.58E+07	
	Sporting goods, hobby, book and music stores		4.67E+06	
	General merchandise stores		1.67E+07	
	Miscellaneous store retailers		6.06E+06	
	Non-store retailers		5.47E+06	
<b>Air transportation [BS48100]</b>	Air transportation	2.66E+05	2.25E+07	1.18E-02
<b>Rail transportation [BS48200]</b>	Rail transportation	8.19E+04	1.39E+07	5.88E-03
<b>Water transportation [BS48300]</b>	Water transportation	6.27E+04	5.42E+06	1.16E-02
<b>Truck transportation [BS48400]</b>	Truck transportation	3.34E+05	5.36E+07	6.23E-03
<b>Transit, ground passenger and scenic and sightseeing transportation, taxi and limousine service and support activities for transportation [BS48B00]</b>	Urban transit systems	7.94E+04	4.30E+06	2.04E-03
	Other transit and ground passenger transportation and scenic and sightseeing transportation		4.00E+06	
	Support activities for transportation		2.83E+07	
	Taxi and limousine service		2.39E+06	
<b>Pipeline transportation [BS48600]</b>	Crude oil and other pipeline transportation	1.75E+05	5.55E+06	1.57E-02
	Pipeline transportation of natural gas		5.60E+06	

<b>Postal service and couriers and messengers [BS49A00]</b>	Postal service	2.94E+04	4.86E+06	2.04E-03
	Couriers and messengers		9.58E+06	
<b>Warehousing and storage [BS49300]</b>	Warehousing and storage	3.59E+03	4.20E+06	8.53E-04
<b>Motion picture and sound recording industries [BS51200]</b>	Motion picture and video industries (except exhibition)	7.84E+03	7.41E+06	8.06E-04
	Motion picture and video exhibition		1.50E+06	
	Sound recording industries		8.13E+05	
<b>Radio and television broadcasting [BS51510]</b>	Radio and television broadcasting	1.97E+03	3.80E+06	2.52E-04
	Pay and specialty television		4.02E+06	
<b>Publishing, pay/specialty services, telecommunications and other information services [BS51B00]</b>	Newspaper publishers	1.80E+04	4.30E+06	2.19E-04
	Periodical, book and directory publishers		4.77E+06	
	Software publishers		9.54E+06	
	Telecommunications		5.66E+07	
	Data processing, hosting, and related services		4.04E+06	
	Other information services		2.84E+06	
<b>Depository credit intermediation and monetary authorities [BS52B00]</b>	Monetary authorities - central bank	3.40E+04	5.02E+05	2.16E-04
	Banking and other depository credit intermediation		8.06E+07	
	Local credit unions		7.95E+06	
	Non-depository credit intermediation		1.08E+07	
	Activities related to credit intermediation		5.19E+06	
	Financial investment services, funds and other financial vehicles		5.22E+07	
<b>Insurance carriers [BS52410]</b>	Insurance carriers	3.25E+03	4.40E+07	5.59E-05
	Agencies, brokerages and other insurance related activities		1.42E+07	
<b>Lessors of real estate [BS53110]</b>	Lessors of real estate	1.83E+05	9.17E+07	1.56E-03
	Offices of real estate agents and brokers and activities related to real estate		2.57E+07	
<b>Owner-occupied dwellings [BS5311A]</b>	Owner-occupied dwellings	0.00E+00	1.64E+08	0.00E+00
<b>Rental and leasing services and lessors of non-financial intangible assets (except copyrighted works) [BS53B00]</b>	Automotive equipment rental and leasing	4.83E+04	5.96E+06	2.19E-03

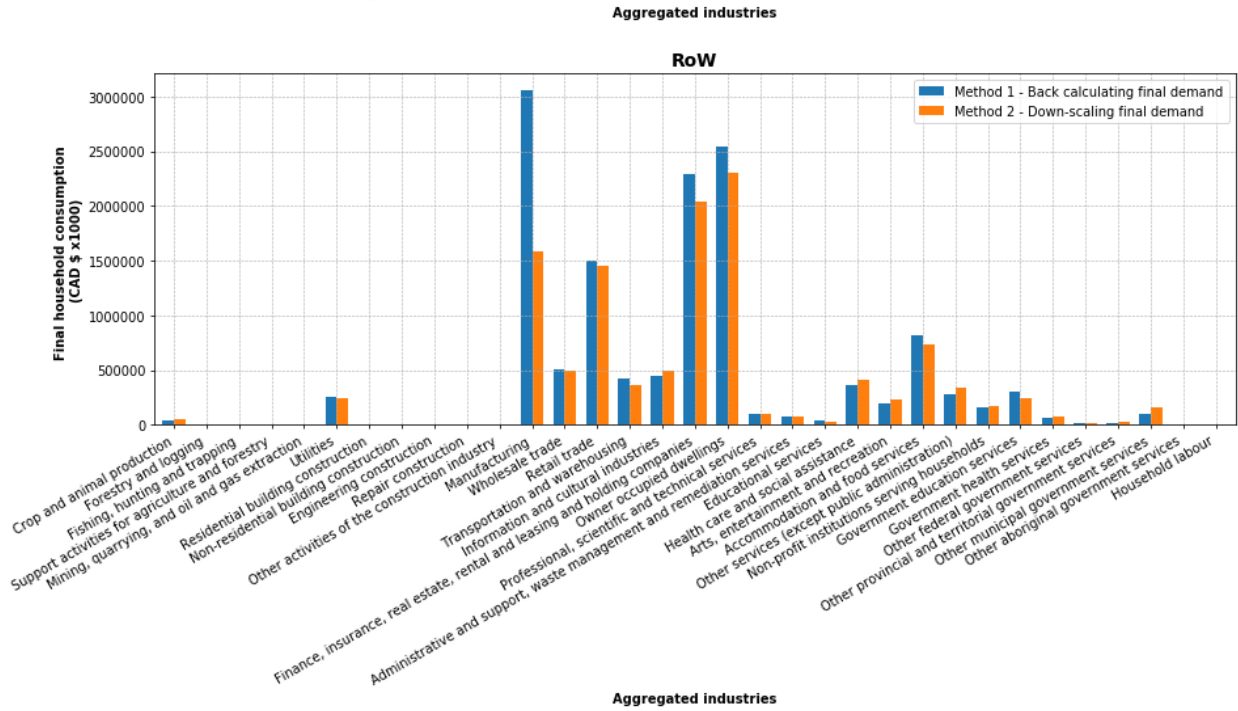
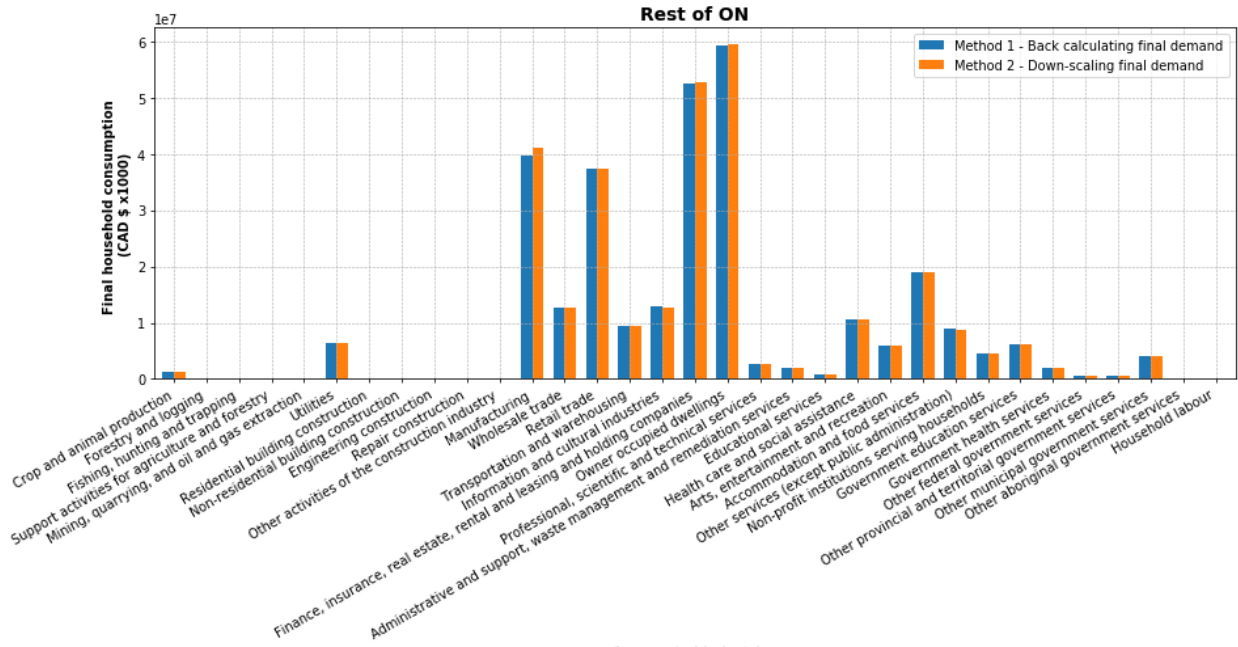
	Rental and leasing services (except automotive equipment)		1.33E+07	
	Lessors of non-financial intangible assets (except copyrighted works)		2.83E+06	
<b>Other finance, insurance and real estate services and management of companies and enterprises [BS5A000]</b>	Holding companies	8.59E+04	2.20E+07	3.91E-03
<b>Legal, accounting and architectural, engineering and related services [BS541C0]</b>	Legal services	2.44E+04	1.81E+07	3.17E-04
	Accounting, tax preparation, bookkeeping and payroll services		1.71E+07	
	Architectural, engineering and related services		3.87E+07	
	Specialized design services		2.95E+06	
<b>Computer systems design and other professional, scientific and technical services [BS541D0]</b>	Computer systems design and related services	2.04E+04	4.29E+07	2.48E-04
	Management, scientific and technical consulting services		1.93E+07	
	Scientific research and development services		7.19E+06	
	Other professional, scientific and technical services		1.29E+07	
<b>Advertising, public relations and related services [BS54180]</b>	Advertising, public relations, and related services	4.18E+03	8.81E+06	4.74E-04
<b>Administrative and support services [BS56100]</b>	Office administrative services	3.86E+04	1.41E+07	5.37E-04
	Facilities and other support services		1.11E+07	
	Employment services		1.21E+07	
	Business support services		7.37E+06	
	Travel arrangement and reservation services		4.82E+06	
	Investigation and security services		6.38E+06	
	Services to buildings and dwellings		1.61E+07	
<b>Waste management and remediation services [BS56200]</b>	Waste management and remediation services	1.74E+04	8.66E+06	2.01E-03
<b>Educational services [BS61000]</b>	Educational services	6.11E+03	6.01E+06	1.02E-03
<b>Health care and social assistance [BS62000]</b>	Offices of physicians	6.11E+04	3.01E+07	8.82E-04
	Offices of dentists		1.52E+07	
	Miscellaneous ambulatory health care services		1.19E+07	
	Nursing and residential care facilities		6.93E+06	
	Social assistance		5.06E+06	

<b>Arts, entertainment and recreation [BS71000]</b>	Performing arts, spectator sports and related industries, and heritage institutions	1.41E+04	8.06E+06	6.17E-04
	Amusement and recreation industries		8.70E+06	
	Gambling industries		6.06E+06	
<b>Accommodation and food services [BS72000]</b>	Traveller accommodation	5.79E+04	1.60E+07	7.12E-04
	RV (recreational vehicle) parks, recreational camps, and rooming and boarding houses		3.24E+06	
	Food services and drinking places		6.22E+07	
<b>Repair and maintenance [BS81100]</b>	Automotive repair and maintenance	5.14E+04	1.20E+07	2.22E-03
	Repair and maintenance (except automotive)		1.12E+07	
<b>Personal services and private households [BS81A00]</b>	Personal care services and other personal services	1.49E+04	1.03E+07	8.30E-04
	Funeral services		1.91E+06	
	Dry cleaning and laundry services		2.46E+06	
	Private households		3.20E+06	
<b>Professional and similar organisations [BS81300]</b>	Professional and similar organizations	1.12E+03	4.11E+06	2.73E-04
<b>Non-profit education services [NP61000]</b>	Educational services	1.35E+04	4.91E+06	2.75E-03
<b>Non-profit social assistance [NP62400]</b>	Social assistance	9.08E+03	9.77E+06	9.29E-04
<b>Non-profit arts, entertainment and recreation [NP71000]</b>	Arts, entertainment and recreation	6.80E+03	2.25E+06	3.03E-03
<b>Religious organizations [NP81310]</b>	Religious organizations	2.37E+04	5.95E+06	3.99E-03
<b>Miscellaneous non-profit institutions serving households [NPA0000]</b>	Ambulatory health care services	3.34E+04	2.09E+06	1.59E-03
	Grant-making, civic, and professional and similar organizations		1.44E+07	
	Other non-profit institutions serving households		4.50E+06	
<b>Educational services (except universities) [GS611B0]</b>	Elementary and secondary schools	6.32E+04	5.75E+07	9.12E-04
	Community colleges and C.E.G.E.P.s		1.12E+07	
	Other educational services		5.04E+05	
<b>Universities [GS61130]</b>	Universities	5.24E+04	4.07E+07	1.29E-03
<b>Hospitals [GS62200]</b>	Hospitals	4.94E+04	9.19E+07	5.37E-04
<b>Nursing and residential care facilities [GS62300]</b>	Nursing and residential care facilities	3.86E+03	1.48E+07	2.60E-04

<b>Other federal government services [GS91100]</b>	Defence services	3.69E+04	1.95E+07	4.99E-04
	Other federal government services (except defence)		5.44E+07	
<b>Other provincial and territorial government services [GS91200]</b>	Other provincial and territorial government services	3.14E+04	1.16E+08	2.70E-04
<b>Other municipal government services [GS91300]</b>	Other municipal government services	1.58E+05	7.92E+07	1.99E-03
<b>Other aboriginal government services [GS91400]</b>	Other aboriginal government services	1.08E+04	6.87E+06	1.57E-03
<b>Households: Motor fuels and lubricants</b>	Wages and salary	1.16E+06	1.11E+09	2.58E-03
<b>Households: Electricity and other fuels</b>	Wages and Salary	1.69E+06		



# Appendix D – Validation of household consumption



## Appendix E – Toy models and supporting calculations

Two toy models were developed to understand the process of model development. One toy model was developed for understanding the process of regionalizing the provincial IO model into a two-region IRIO model. Another toy model was developed to understand how adaptive reuse recipe changes affect the provincial IO model.

### **Two region interregional input output model**

A small scale two region IRIO model was developed to understand the process of model development, as well as to ensure that modeling methodology maintains accounting balance of industry inputs and outputs. This toy model mirrors the steps taken in the development of the two-region IRIO model for RoW and Rest of Ontario. To reiterate, the steps in developing the existing regional model were

1. Import scrubbed Ontario Use matrix to determine domestic use of commodities
2. Convert Make and Use tables into symmetric IO model for Ontario
3. Endogenous provincial IO model with respect to households
4. Regionalize Ontario IO model into two regions using cross-industry location quotients and develop a two-region IRIO model.

The two-region IRIO model for adaptive reuse scenarios followed the same steps mentioned above, except changes to the construction industry's commodity usage were applied before import scrubbing. Development of this toy model has helped in the understanding of IO models. One major finding pertains to the step where households are endogenized. It was found that imports to household consumptions needed to be concatenated to the  $n+1$  cell of the value-added vectors. Recall that imports to household consumption is found by the difference between the sum of household consumption and household labour. This concatenation of the value-added vectors was crucial in maintaining industry inputs and outputs. Another finding is in import scrubbing, imports are 'moved' from final demand into value-added, in order to maintain accounting balances. The values of these imports were found by subtracting the 'scrubbed' and 'non-scrubbed' value-added vectors. The last major finding from the toy model is that changes to the construction recipes (to reflect adaptive reuse of buildings) needed to be made before the import scrubbing. This was necessary as making changes to the construction recipes post import scrubbing would mean that regions would not change their dependence on imports

# EXISTING: Experimental Make and Use tables

		Commodity		industry		commodity final demand, e = g + hh		import		Commodity output		
						Other final demand	household					
						g	hh					
		1	2	1	2			m	q			
Commodity	1	Use matrix		2	2	5	2	-2	9			
	2	>>		3	4	5	2	-4	10			
Industry	1	4	6	Make Matrix						x		
	2	5	4	<<						10		
Value added	labour	s	2.7		1.3							
	other value added	w	2.3		1.7							
	Total value added	gva	5		3							
										x		
										10		
										9		

## IMPORT SCRUBBING

U_scrubbed	1.636 1.636 2.143 2.857	e_scrubbed	5.72727 5	q	9 10
B_scrubbed	0.164 0.182 0.214 0.317	e_imports	-1.27273 -2	Import scrubbing factor	
D	0.444 0.6 0.556 0.4	r	-0.18182 -0.28571	hh_prop is calculated by dividing D*hh by D*e	
A_scrubbed	0.201 0.271 0.177 0.228	D_hh_prop	ind 1 0.285714 ind 2 0.285714		
L_scrubbed	1.358 0.477 0.311 1.404	f_scrubbed	5.545 5.182	x	
Z_scrubbed	2.013 2.442 1.766 2.052			10 9	
gva		5 3			
gva_scrubbed		6.221 4.506			
gva_imports = gva_scrubbed - gva		1.221 1.506			

## EXISTING: Import Scrubbing cont'd

Column ID	col_1	col_2	col_3	col_4
		hh_col_pro	hh_scrubbed =	final demand
	f_scrubbed	p	col_1 * col_2	excluding hh =
				col_1 - col3
industry 1	5.545	0.286	1.584	3.961
industry 2	5.182	0.286	1.481	3.701

the household column no longer balances with the household row.

			ind 1	ind 2	total
Value added	labour	s	2.7	1.3	4
	other value added	w	2.3	1.7	4
	imports	gva_m	1.221	1.506	
	<b>Total</b>		6.221	4.506	

the difference is calculated by subtracting sum of hh\_scrubbed, and sum of s. This difference is the imports that goes to household expenditure

hh\_diff 0.93506

### Closing provincial wrt household

household column from from final demand, and household row from value added was moved into the transaction matrix

<b>Z_scrubbed</b>	<table border="1"> <tr><td>2.013</td><td>2.442</td><td>1.584</td></tr> <tr><td>1.766</td><td>2.052</td><td>1.481</td></tr> <tr><td>2.700</td><td>1.300</td><td>0.000</td></tr> </table>	2.013	2.442	1.584	1.766	2.052	1.481	2.700	1.300	0.000	<b>f_scrub</b>	<table border="1"> <tr><td>3.96</td></tr> <tr><td>3.70</td></tr> <tr><td>0.00</td></tr> </table>	3.96	3.70	0.00
2.013	2.442	1.584													
1.766	2.052	1.481													
2.700	1.300	0.000													
3.96															
3.70															
0.00															
<b>L_scrub</b>	<table border="1"> <tr><td>1.76892</td><td>0.808703</td><td>1</td></tr> <tr><td>0.680835</td><td>1.70297</td><td>0.9</td></tr> <tr><td>0.57595</td><td>0.464334</td><td>1.4</td></tr> </table>	1.76892	0.808703	1	0.680835	1.70297	0.9	0.57595	0.464334	1.4	<b>x_scrub</b>	<table border="1"> <tr><td>10</td></tr> <tr><td>9</td></tr> <tr><td>4</td></tr> </table>	10	9	4
1.76892	0.808703	1													
0.680835	1.70297	0.9													
0.57595	0.464334	1.4													
10															
9															
4															
<b>A_scrub</b>	<table border="1"> <tr><td>0.201299</td><td>0.271284</td><td>0.396104</td></tr> <tr><td>0.176623</td><td>0.227994</td><td>0.37013</td></tr> <tr><td>0.27</td><td>0.144444</td><td>0</td></tr> </table>	0.201299	0.271284	0.396104	0.176623	0.227994	0.37013	0.27	0.144444	0					
0.201299	0.271284	0.396104													
0.176623	0.227994	0.37013													
0.27	0.144444	0													
<b>gva_scrub</b>	<table border="1"> <tr><td>3.52078</td><td>3.20649</td><td>0.935065</td></tr> </table>	3.52078	3.20649	0.935065											
3.52078	3.20649	0.935065													

# EXISTING: Two Region IRIO Model

## Get location quotients

employment	region 1	region 2	total
ind 1	4	20	24
ind 2	6	31	37
household	20	70	90

Cross industry location quotients were calculated using employment numbers

**CILQ for region 1**

	ind 1	ind 2	hh
ind 1	0.838889	1	0.75
ind 2	0.973	0.816	0.72973
hh	1	1	1

**CILQ for region 2**

	ind 1	ind 2	hh
ind 1	1.000	0.995	1
ind 2	1	1	1
hh	0.933333	0.928315	0.970615

Use cross industry location quotient to separate provincial model into two regions: region 'r' and 'sr'

**A<sub>r\_r</sub>**

0.1689	0.2713	0.2971
0.1718	0.1861	0.2701
0.2700	0.1444	0.0000

**A<sub>r\_sr</sub>**

0.00	0.00	0.00
0.00	0.00	0.00
0.02	0.01	0.00

**f<sub>r</sub>**

0.71
0.66
0.00

**A<sub>sr\_r</sub>**

0.03	0.00	0.10
0.00	0.04	0.10
0.00	0.00	0.00

**A<sub>sr\_sr</sub>**

0.201	0.270	0.396
0.177	0.228	0.370
0.252	0.134	0.000

**f<sub>sr</sub>**

3.25
3.04
0.00

**Z<sub>r\_r</sub>**

0.28	0.40	0.26
0.29	0.27	0.24
0.45	0.21	0.00

**Z<sub>r\_sr</sub>**

0.00	0.01	0.00
0.00	0.00	0.00
0.15	0.08	0.00

**x<sub>r</sub>**

1.67
1.46
0.89

**Z<sub>sr\_r</sub>**

0.05	0.00	0.09
0.01	0.06	0.09
0.00	0.00	0.00

**Z<sub>sr\_sr</sub>**

1.68	2.03	1.23
1.47	1.72	1.15
2.10	1.01	0.00

**x<sub>sr</sub>**

8.33
7.54
3.11

**w<sub>r</sub>**

0.587	0.520	0.208
-------	-------	-------

**w<sub>sr</sub>**

2.93	2.69	0.73
------	------	------

**EXISTING: Closing two region IRIO model wrt  
households cont'd**

---

<b>Z_irio</b>		region 1			region 1			<b>f_irio</b>	<b>x_irio</b>
		ind 1	ind 2	hh	ind 1	ind 2	hh		
region 1	ind 1	0.28	0.40	0.26	0.00	0.01	0.00	0.71	1.67
	ind 2	0.29	0.27	0.24	0.00	0.00	0.00	0.66	1.46
	hh	0.45	0.21	0.00	0.15	0.08	0.00	0.00	0.89
region 2	ind 1	0.05	0.00	0.09	1.68	2.03	1.23	3.25	8.33
	ind 2	0.01	0.06	0.09	1.47	1.72	1.15	3.04	7.54
	hh	0.00	0.00	0.00	2.10	1.01	0.00	0.00	3.11
<b>v_irio</b>		0.587	0.520	0.208	2.93	2.69	0.73		

<b>A_irio</b>		region 1			region 1		
		ind 1	ind 2	hh	ind 1	ind 2	hh
region 1	ind 1	0.17	0.27	0.30	0.00	0.00	0.00
	ind 2	0.17	0.19	0.27	0.00	0.00	0.00
	hh	0.27	0.14	0.00	0.02	0.01	0.00
region 2	ind 1	0.03	0.00	0.10	0.20	0.27	0.40
	ind 2	0.00	0.04	0.10	0.18	0.23	0.37
	hh	0.00	0.00	0.00	0.25	0.13	0.00

### Adaptive reuse changes to IO model

The effects of adaptive reuse recipe changes on the provincial IO model was studied by first developing a hypothetical base case economy. The base case economy was represented with a symmetric IO model and developed with three steps

1. Import scrub the transaction matrix and final demand to get domestic economy.
2. Endogenize the household sector (move household labour and household consumption into the transaction matrix)
3. Develop the closed IO model:  $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$

For the economy where adaptive reuse is applied, the model was developed in five steps

1. Apply adaptive reuse recipe changes to industry inputs (interindustry, and value added inputs), and adjust imports proportionate to recipe reductions
2. Import scrub the transaction matrix and final demand to get domestic economy
3. Endogenize the household sector (move household labour and household consumption into the transaction matrix)
4. Develop the closed IO model:  $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}$
5. Apply price changes to adaptive reuse buildings (changing final demand), and develop new closed IO model:  $\mathbf{x}^{new} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}^{new}$

These toy models were primarily used to figure out how to calculate changes to GDP on the output side of the IO model. Import scrubbing removes imports from the final demand, so GDP cannot be intuitively calculated on the output side (using final demand). GDP can still be calculated through input side (value-added). However, GDP calculation checks were done on the output side to verify input side GDP calculations.

The findings in developing these toy models are summarized below

1. When making changes to industry recipe and value added, GDP change is equal the total reduction in imports in value added
2. When making changes to final demand in an open IO model, GDP change is equal the total reduction in imports in value added plus total changes in final demand
3. When making changes to final demand in a closed IO model, GDP change is equal the total reduction in imports to non household sectors plus total changes in final demand plus total changes to household consumption (endogenized in transaction matrix)





## Hypothetical Base Case + changes to value added and industry recipe

industry 2 uses 20 less of industry 1, hh labour goes up 10. value added has to increase by 20-10 = 10

Output from Sector	Input to Sector		Intermediate Output (O)	household consumption	Domestic Consumption	Exports	Imports	Total Output
	1	2						
1	225	690	915	45	130	200	-305.267	984.73282
2	575	1400	1975	65	785	800	-625	3000
Intermediate Input	800	2090				Check		
hh labour	50	70				r1	0.236641	OK
Value Added	150	840				r2	0.172414	OK
Total Output	1000	3000						
							GDP	1110

Scrub imports out of transactions. Imports added to value added

Output from Sector	Input to Sector		Intermediate Output (O)	household consumption	Domestic Consumption	Exports	Imports	Total Output
	1	2						
1	171.756	526.718	698.4732824	34.35114504	99.23664122	152.6718		984.73282
2	475.862	1158.62	1634.482759	53.79310345	649.6551724	662.069		3000
Intermediate Input	647.618	1685.34						
hh labour	50	70						
Value Added	150	840						
Imports	152.382	404.662						
Total Output	1000	3000						

### Calculate model

A - technical coefficient matrix

	ind 1	ind 2
ind 1	0.17176	0.17557
ind 2	0.47586	0.38621

household proportion

	ind 1	ind 2
ind 1	0.1200	
ind 2	0.0394	

I - identity matrix

	ind 1	ind 2
ind 1	1	0
ind 2	0	1

f - final demand vector

	ind 1	ind 2
ind 1	286.26	
ind 2	1365.52	

Value added coefficients

	ind 1	ind 2
lab_coeff	0.05	0.023333
va_coeff	0.15	0.28
imp_coeff	0.152382206	0.134887

X - output vector

	ind 1	ind 2
ind 1	977.942	
ind 2	2982.9	

GDP 1100.400892

## Hypothetical Base Case + changes to value added and industry recipe

### Scrub imports out of transactions. Imports added to value added

Output from Sector	Input to Sector		Intermediate Output (O)	household consumption	Domestic Consumption	Total Output
	1	2				
1	167.96707	523.715	691.6820901	34.35114504	251.9083969	977.9416321
2	465.36533	1152.016	1617.381327	53.79310345	1311.724138	2982.898569
Intermediate Input	633.3324	1675.731				
hh labour	48.897082	69.60097		GDP		Check
Value Added	146.69124	835.2116		1100.400892		Original GDP 1090
Imports	149.0209	402.355				Import Change 10.40089
Total Output	977.94163	2982.899				Total 1100.40089

Close tables with respect to households. Imports to household industry is the total difference between household consumption and household labor

Output from Sector	Input to Sector		hh consumption	Intermediate Output (O)	Domestic Consumption	Total Output
	1	2				
1	167.96707	523.715	34.35114504	726.0332351	251.9083969	977.9416321
2	465.36533	1152.016	53.79310345	1671.174431	1311.724138	2982.898569
hh	48.897082	69.60097	0	118.4980482	0	118.4980482
Intermediate Input	682.22948	1745.332	88.14424849			
Value Added	146.69124	835.2116				
Imports	149.0209	402.355	30.35379972			
Total Output	977.94163	2982.899	118.4980482			

A - technical coefficient matrix

	ind 1	ind 2	hh
ind 1	0.1717557	0.175573	0.289887855
ind 2	0.4758621	0.386207	0.453957717
hh	0.05	0.023333	0

f - final demand vector

ind1	251.908
ind2	1311.72
hh	0

I - identity matrix

	ind 1	ind 2	hh
ind 1	1	0	0
ind 2	0	1	0
hh	0	0	1

X - output vector

ind1	977.942
ind2	2982.9
hh	118.498

Value added coefficients

	ind1	ind2	hh
lab coeff	0.0500	0.0233	0.0000
va_coeff	0.1500	0.2800	0.0000
imp_coeff	0.1524	0.1349	0.2562

## Hypothetical Base Case + changes to value added and industry recipe

### Increase final demand of industry 1 by 20 %

f - new final demand vector

ind1	302.29008
ind2	1311.7241
hh	0

X - new ooutput vector

ind1	1053.92702
ind2	3045.702322
hh	123.7627385

### Calculate new transaction matrix, value added, imports and GDP

	Input to Sector		hh	Intermediate	Domestic	Total	
	1	2	consumption	Output (O)	Consumption		Output
Output from S	1	181.018	534.74163	35.87731482	751.6369434	302.2900763	1053.927
	2	501.52389	1176.2712	56.18305023	1733.978184	1311.724138	3045.7023
hh		52.696351	71.066388	0	123.7627385	0	123.76274
Intermediate							
Input		735.23824	1782.0793	92.06036505			
Value Added		158.08905	852.79665	0			
Imports		160.59972	410.82641	31.70237345			
Total Output		1053.927	3045.7023	123.7627385			

**GDP**  
1134.6484

Check	
Original GDP	1090
Import Change	-9.64935
Final demand change	50.381679
hh consumption change	3.9161166
Total	1134.6484

### Sample calculations of final demand changes reflecting adaptive reuse

Recall from Chapter 3.7 that the final demand recipe change is calculated as

$$f^{new} = [i - (\beta \alpha)]f \quad (3.73)$$

Where positive  $\alpha$  represents decrease in price, and negative  $\alpha$  represents increase in price. For example, the element-by-element calculations for 'Industrial buildings' for the scenarios with 10% increase in price would be

$$\begin{aligned} f_{Industrial\ buildings}^{new} &= (1 - \beta\alpha)f_{Industrial\ buildings}^{existing} \\ f_{Industrial\ buildings}^{new} &= (1 - 0.2[-0.1]) \times 15\ 009\ 509 \\ f_{Industrial\ buildings}^{new} &= 15\ 084\ 556 \end{aligned}$$

## Appendix F – Changes to Use matrix to reflect adaptive reuse of buildings

Table F1 – RoW changes to residential building construction recipe

Residential building construction, $\beta = 0.2$					
Commodity	Scenarios				
	Existing	Basic	10%	45%	90%
Textile products, n.e.c.	33610	33610	32937.8	30585.1	27560.2
Hardwood lumber	952	952	932.96	866.32	780.64
Softwood lumber	402416	402416	394367.68	366198.56	329981.12
Other sawmill products and treated wood products	218762	218762	214386.76	199073.42	179384.84
Veneer and plywood	216021	216021	211700.58	196579.11	177137.22
Wood trusses and engineered wood members	268569	268569	263197.62	244397.79	220226.58
Reconstituted wood products	165767	165767	162451.66	150847.97	135928.94
Wood windows and doors	316654	316654	310320.92	288155.14	259656.28
Prefabricated wood and manufactured (mobile) buildings and components	426729	426729	418194.42	388323.39	349917.78
Wood products, n.e.c.	628115	628115	615552.7	571584.65	515054.3
Plastic and foam building and construction materials	803492	803492	787422.16	731177.72	658863.44
Plastic products, n.e.c.	291397	291397	285569.06	265171.27	238945.54
Rubber products, n.e.c.	73341	73341	71874.18	66740.31	60139.62
Clay and ceramic products and refractories	145978	145978	143058.44	132839.98	119701.96
Glass (including automotive), glass products and glass containers	193300	193300	189434	175903	158506
Lime and gypsum products	233359	233359	228691.82	212356.69	191354.38
Non-metallic mineral products, n.e.c.	197851	197851	193893.98	180044.41	162237.82
Iron and steel basic shapes and ferro-alloy products	602	602	589.96	547.82	493.64
Iron and steel pipes and tubes (except castings)	17694	17694	17340.12	16101.54	14509.08
Wire and other rolled and drawn steel products	3302	3302	3235.96	3004.82	2707.64
Forged and stamped metal products	69276	69276	67890.48	63041.16	56806.32
Metal windows and doors	570676	570676	559262.48	519315.16	467954.32
Boilers, tanks and heavy gauge metal containers	97293	97293	95347.14	88536.63	79780.26
Springs and wire products	89235	89235	87450.3	81203.85	73172.7
Threaded metal fasteners and other turned metal products including automotive	149324	149324	146337.52	135884.84	122445.68
Metal valves and pipe fittings	126838	126838	124301.24	115422.58	104007.16
Fabricated metal products, n.e.c.	681113	681113	667490.74	619812.83	558512.66

Heating and cooling equipment (except household refrigerators and freezers)	634368	634368	621680.64	577274.88	520181.76
Other electronic components	6679	6679	6545.42	6077.89	5476.78
Electric light bulbs and tubes	46528	46528	45597.44	42340.48	38152.96
Lighting fixtures	143334	143334	140467.32	130433.94	117533.88
Small electric appliances	4380	4380	4292.4	3985.8	3591.6
Major appliances	87120	87120	85377.6	79279.2	71438.4
Switchgear, switchboards, relays and industrial control apparatus	38802	38802	38025.96	35309.82	31817.64
Wood kitchen cabinets and counter tops	764409	764409	749120.82	695612.19	626815.38
Wholesale margins - building materials and supplies	1316226.00	1316226.00	1289901.48	1197765.66	1079305.32
Retail margins - furniture and home furnishings	187027	187027	183286.46	170194.57	153362.14
Retail margins - building materials, garden equipment and supplies	731284	731284	716658.32	665468.44	599652.88

Table F2 – RoW changes to non-residential building construction reipe

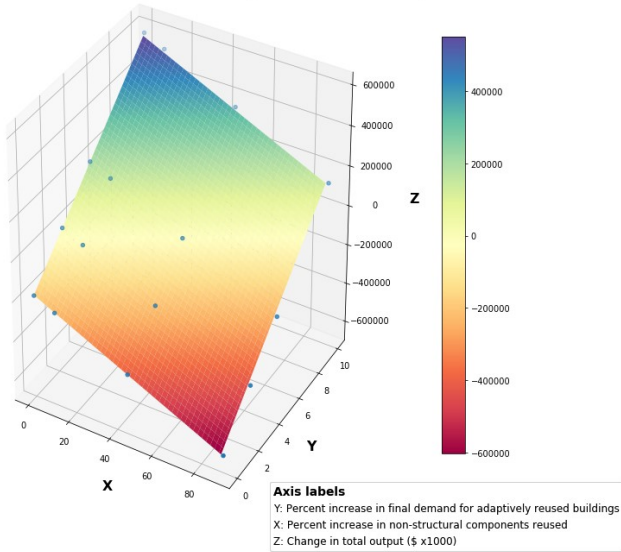
Non-residential building construction,  $\beta = 0.2$

Commodity	Scenarios				
	Existing	Base	10%	45%	90%
Textile products, n.e.c.	9472	9472	9282.56	8619.52	7767.04
Hardwood lumber	10	10	9.8	9.1	8.2
Softwood lumber	17443	17443	17094.14	15873.13	14303.26
Other sawmill products and treated wood products	16576	16576	16244.48	15084.16	13592.32
Veneer and plywood	15258	15258	14952.84	13884.78	12511.56
Wood trusses and engineered wood members	7709	7709	7554.82	7015.19	6321.38
Reconstituted wood products	12594	12594	12342.12	11460.54	10327.08
Wood windows and doors	5613	5613	5500.74	5107.83	4602.66
Prefabricated wood and manufactured (mobile) buildings and components	69474	69474	68084.52	63221.34	56968.68
Wood products, n.e.c.	23078	23078	22616.44	21000.98	18923.96
Plastic and foam building and construction materials	193982	193982	190102.4	176523.6	159065.2
Plastic products, n.e.c.	67033	67033	65692.34	61000.03	54967.06
Rubber products, n.e.c.	15970	15970	15650.6	14532.7	13095.4
Clay and ceramic products and refractories	63348	63348	62081.04	57646.68	51945.36
Glass (including automotive), glass products and glass containers	70084	70084	68682.32	63776.44	57468.88
Lime and gypsum products	27188	27188	26644.24	24741.08	22294.16
Non-metallic mineral products, n.e.c.	170833	170833	167416.3	155458	140083.1

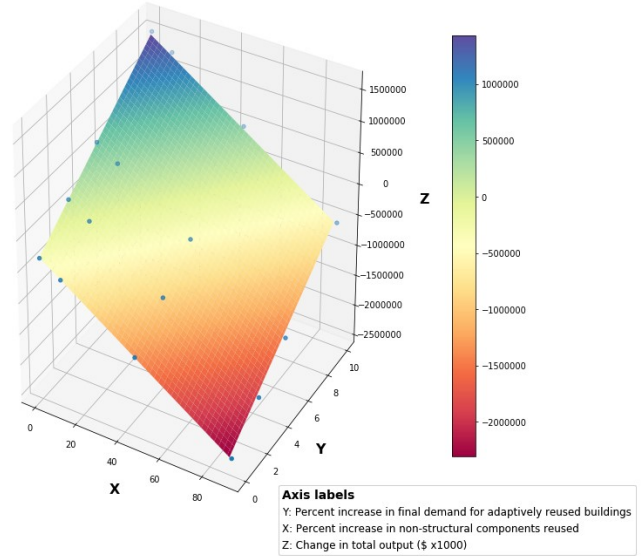
<b>Iron and steel basic shapes and ferro-alloy products</b>	370	370	362.6	336.7	303.4
<b>Iron and steel pipes and tubes (except castings)</b>	23657	23657	23183.86	21527.87	19398.74
<b>Wire and other rolled and drawn steel products</b>	3460	3460	3390.8	3148.6	2837.2
<b>Forged and stamped metal products</b>	14601	14601	14308.98	13286.91	11972.82
<b>Metal windows and doors</b>	93812	93812	91935.76	85368.92	76925.84
<b>Boilers, tanks and heavy gauge metal containers</b>	78487	78487	76917.26	71423.17	64359.34
<b>Springs and wire products</b>	61597	61597	60365.06	56053.27	50509.54
<b>Threaded metal fasteners and other turned metal products including automotive</b>	73805	73805	72328.9	67162.55	60520.1
<b>Metal valves and pipe fittings</b>	113368	113368	111100.6	103164.9	92961.76
<b>Fabricated metal products, n.e.c.</b>	236955	236955	232215.9	215629.1	194303.1
<b>Heating and cooling equipment (except household refrigerators and freezers)</b>	143860	143860	140982.8	130912.6	117965.2
<b>Other electronic components</b>	9836	9836	9639.28	8950.76	8065.52
<b>Electric light bulbs and tubes</b>	29926	29926	29327.48	27232.66	24539.32
<b>Lighting fixtures</b>	134451	134451	131762	122350.4	110249.8
<b>Small electric appliances</b>	4560	4560	4468.8	4149.6	3739.2
<b>Major appliances</b>	16028	16028	15707.44	14585.48	13142.96
<b>Switchgear, switchboards, relays and industrial control apparatus</b>	50678	50678	49664.44	46116.98	41555.96
<b>Wood kitchen cabinets and counter tops</b>	14055	14055	13773.9	12790.05	11525.1
<b>Wholesale margins - building materials and supplies</b>	341212	341212	334387.8	310502.9	279793.8
<b>Retail margins - furniture and home furnishings</b>	49961	49961	48961.78	45464.51	40968.02
<b>Retail margins - building materials, garden equipment and supplies</b>	138010	138010	135249.8	125589.1	113168.2

# Appendix G – 3D plots

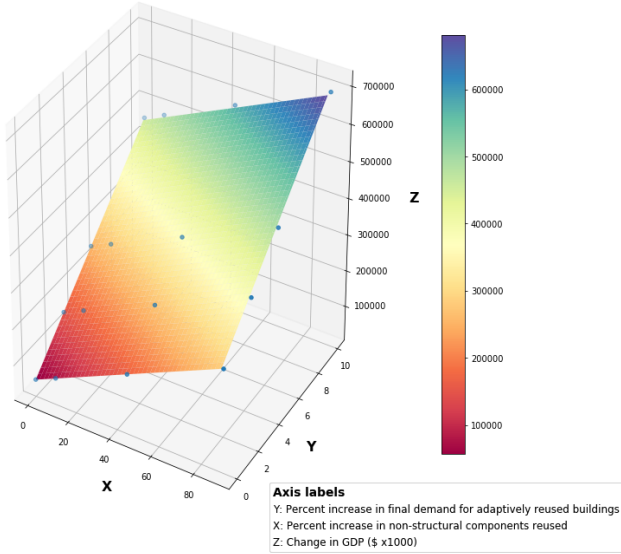
**Change in total output for Ontario resulting from Adaptive reuse of Non-residential building construction industry**



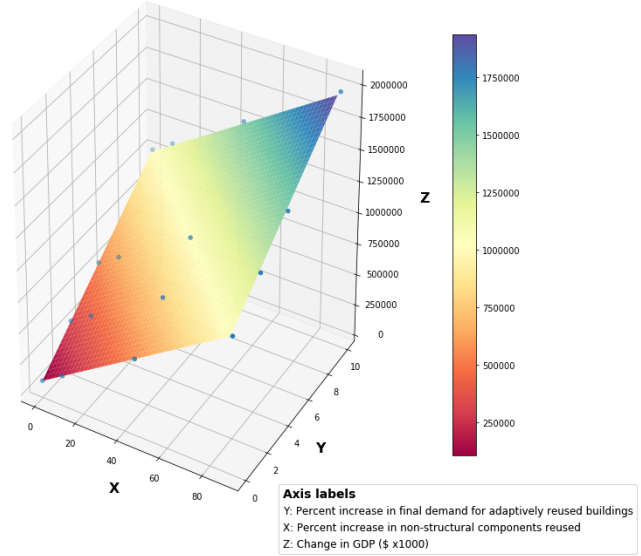
**Change in total output for Ontario resulting from Adaptive reuse of Residential building construction industry**



**Change in GDP for Ontario resulting from adaptive reuse of Non-residential building construction industry**

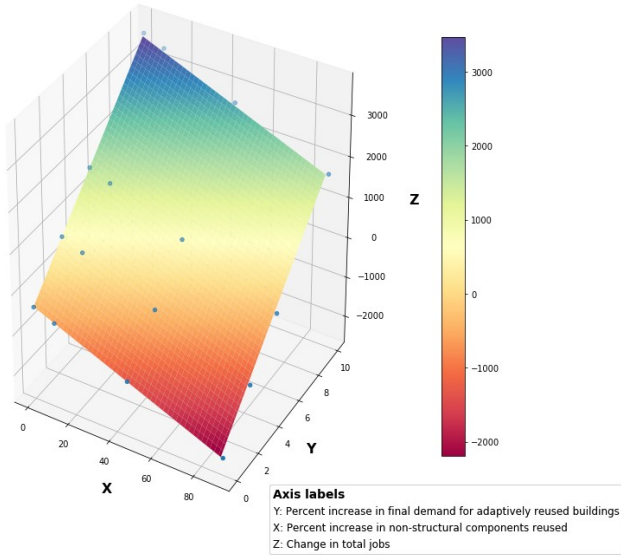


**Change in GDP for Ontario resulting from adaptive reuse of Residential building construction industry**

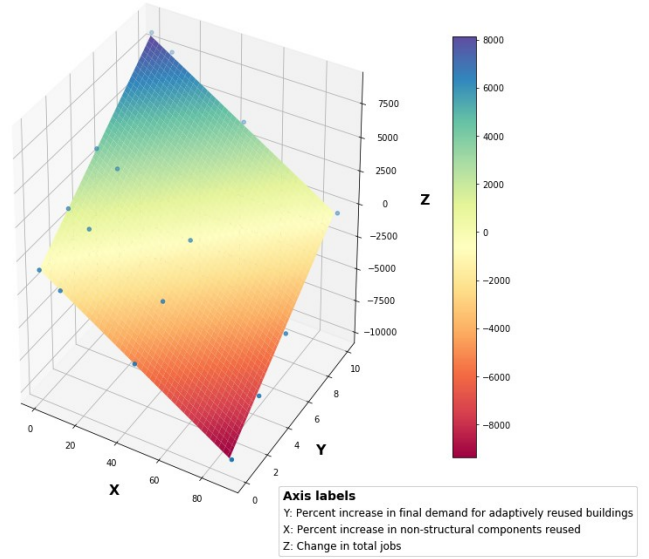




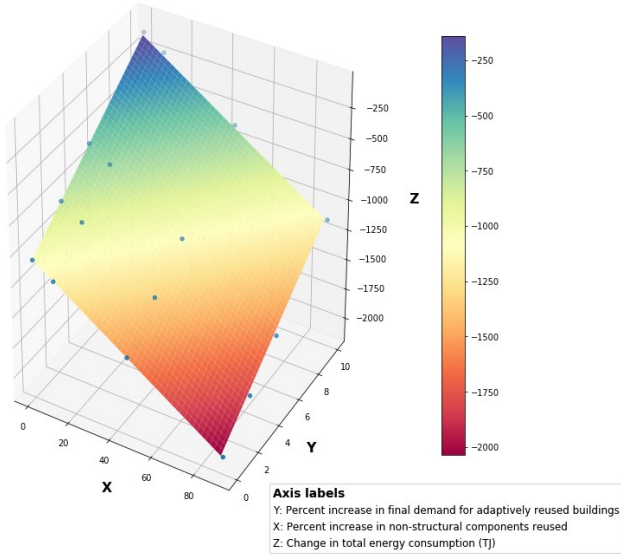
**Change in total jobs in Ontario resulting from adaptive reuse of Non-residential building construction industry**



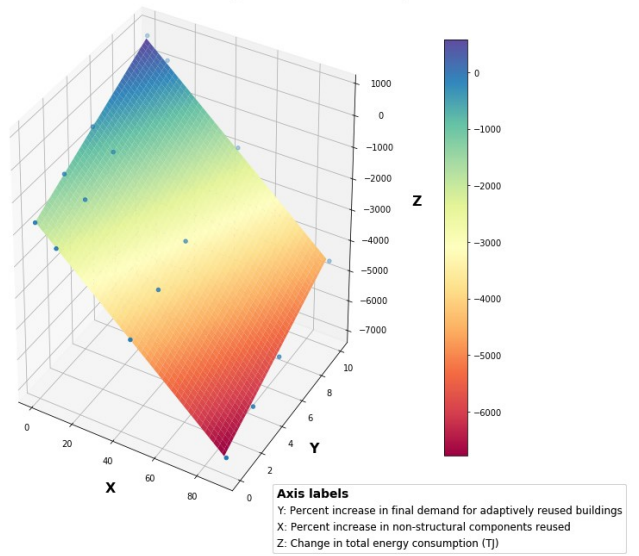
**Change in total jobs in Ontario resulting from adaptive reuse of Residential building construction industry**



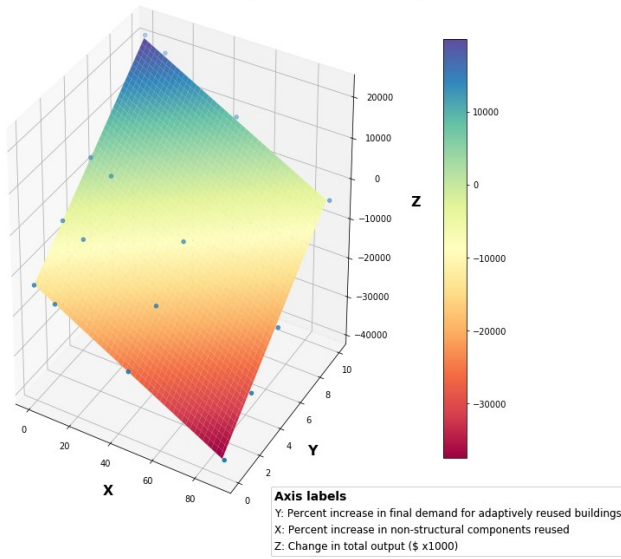
**Change in total energy consumption in Ontario resulting from adaptive reuse of Non-residential building construction industry**



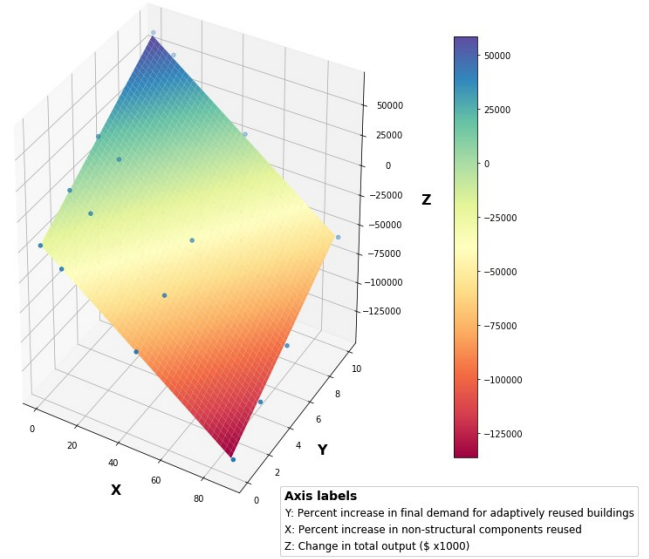
**Change in total energy consumption in Ontario resulting from adaptive reuse of Residential building construction industry**



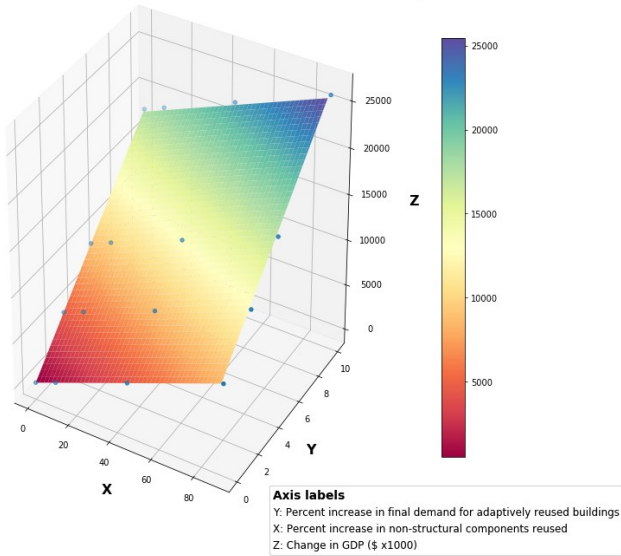
**Change in total output for RoW resulting from adaptive reuse of Non-residential building construction industry**



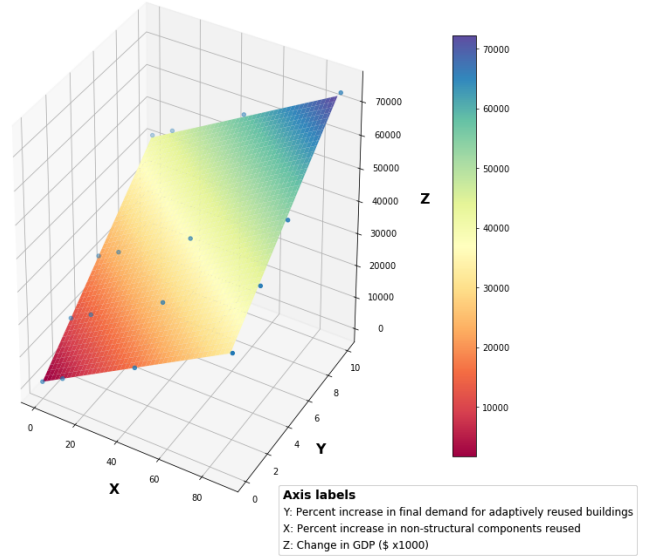
**Change in total output for RoW resulting from adaptive reuse of Residential building construction industry**



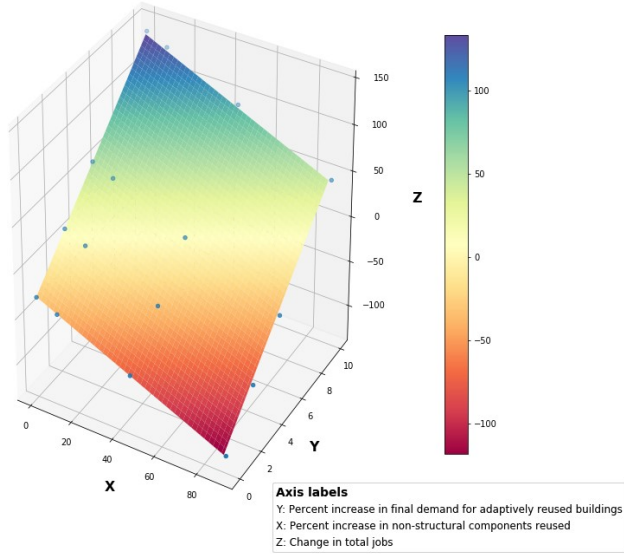
**Change in GDP for RoW resulting from adaptive reuse of Non-residential building construction industry**



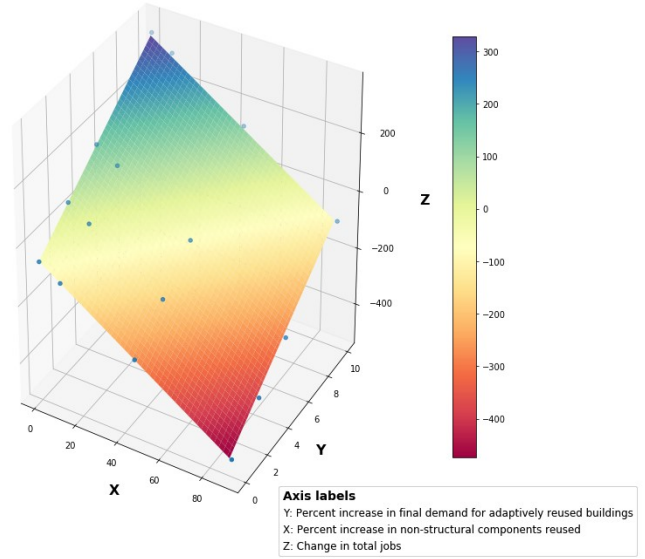
**Change in GDP for RoW resulting from adaptive reuse of Residential building construction industry**



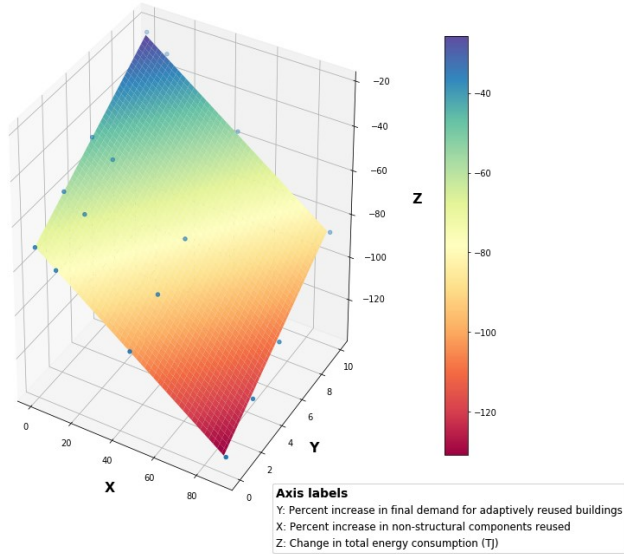
**Change in total jobs in RoW resulting from adaptive reuse of Non-residential building construction industry**



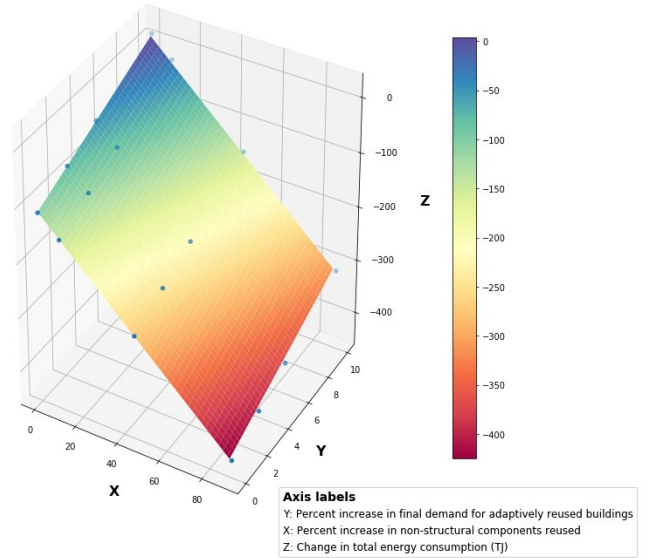
**Change in total jobs in RoW resulting from adaptive reuse of Residential building construction industry**



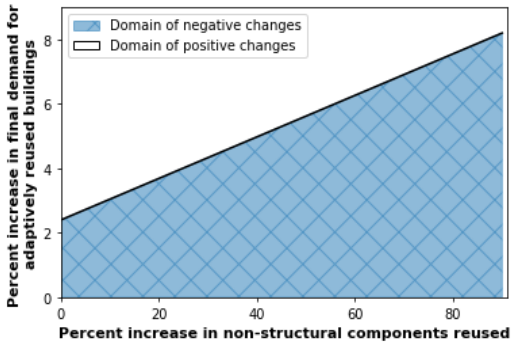
**Change in total energy consumption in RoW resultign from adaptive reuse of Non-residential building construction industry**



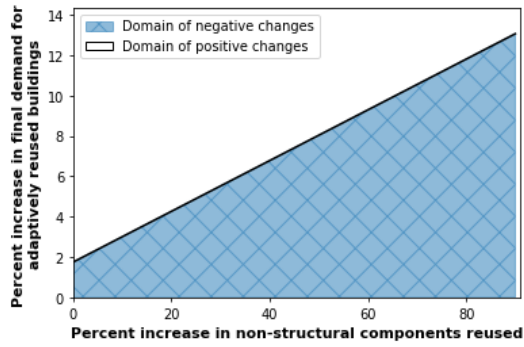
**Change in total energy consumption in RoW resultign from adaptive reuse of Residential building construction industry**



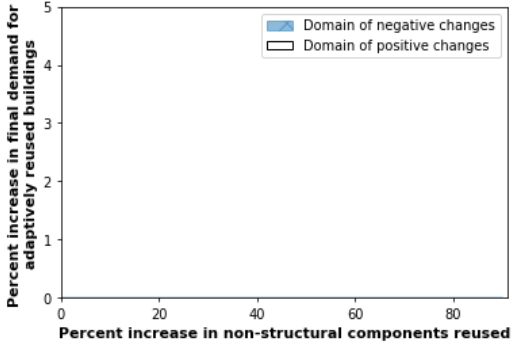
**Domain of negative change of total output for Ontario:  
adaptive reuse of  
Non-residential building construction industry**



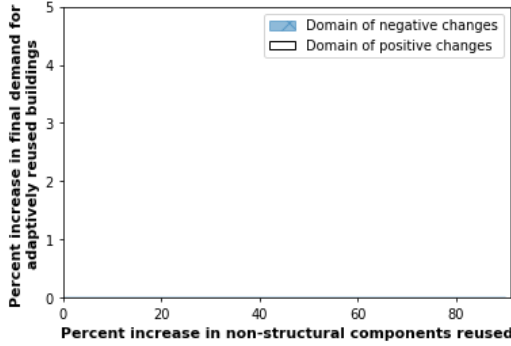
**Domain of negative change of total output for Ontario:  
adaptive reuse of  
Residential building construction industry**



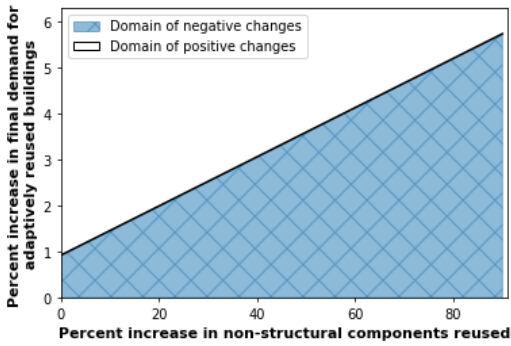
**Domain of negative GDP change in Ontario:  
adaptive reuse of  
Non-residential building construction industry**



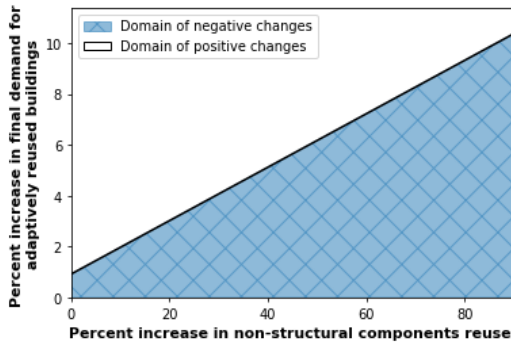
**Domain of negative GDP change in Ontario:  
adaptive reuse of  
Residential building construction industry**



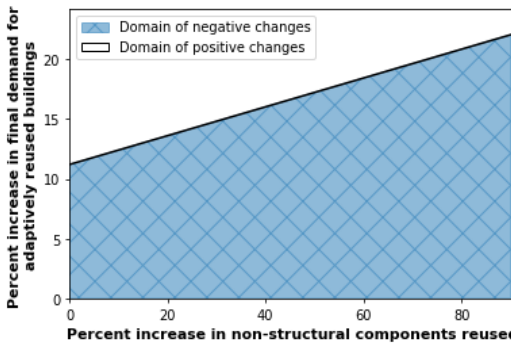
**Domain of job losses in Ontario:  
adaptive reuse of  
Non-residential building construction industry**



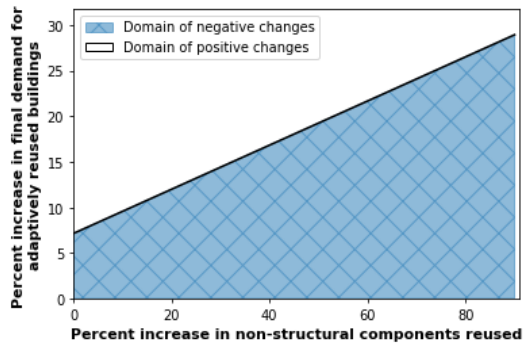
**Domain of job losses in Ontario:  
adaptive reuse of  
Residential building construction industry**



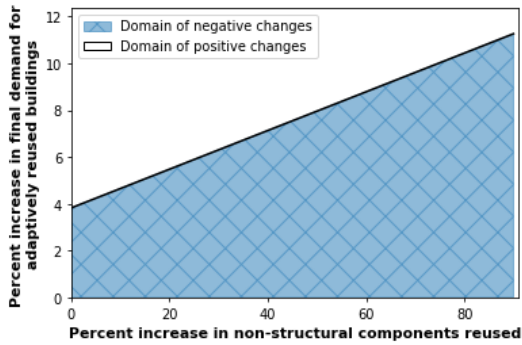
**Domain of negative change in energy use in Ontario:  
adaptive reuse of  
Non-residential building construction industry**



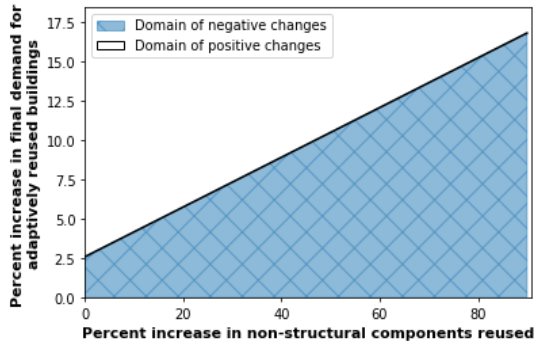
**Domain of negative change in energy use in Ontario:  
adaptive reuse of  
Residential building construction industry**



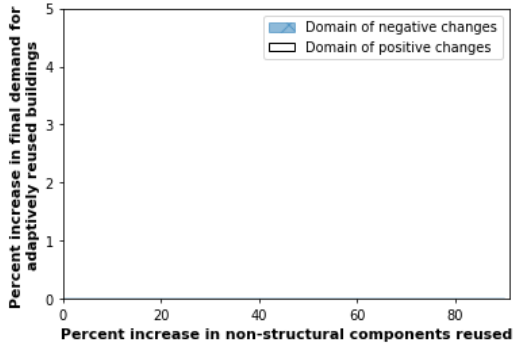
**Domain of negative change of total output for RoW:  
adaptive reuse of  
Non-residential building construction industry**



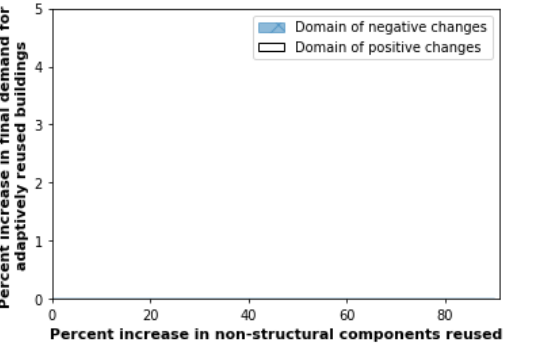
**Domain of negative change of total output for RoW:  
adaptive reuse of  
Residential building construction industry**



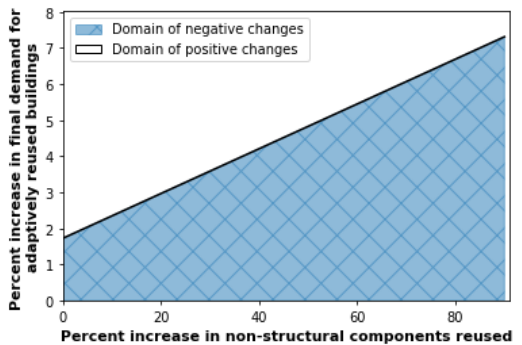
**Domain of negative change of GDP in RoW:  
adaptive reuse of  
Non-residential building construction industry**



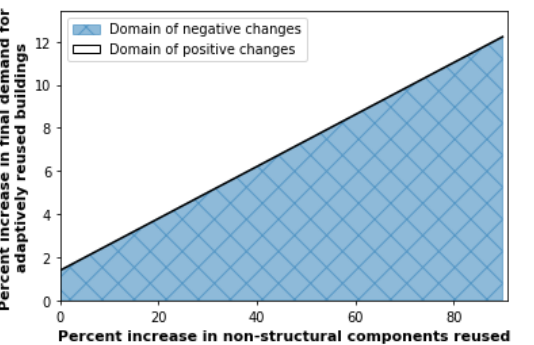
**Domain of negative change of GDP in RoW:  
adaptive reuse of  
Residential building construction industry**



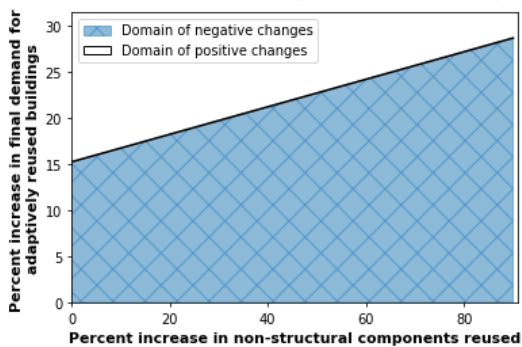
**Domain of job losses in RoW:  
adaptive reuse of  
Non-residential building construction industry**



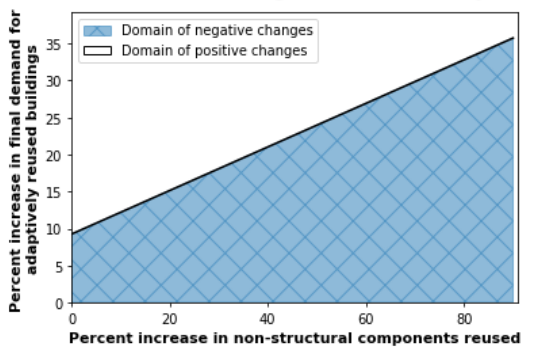
**Domain of job losses in RoW:  
adaptive reuse of  
Residential building construction industry**



**Domain of negative change in energy use in RoW:  
adaptive reuse of  
Non-residential building construction industry**

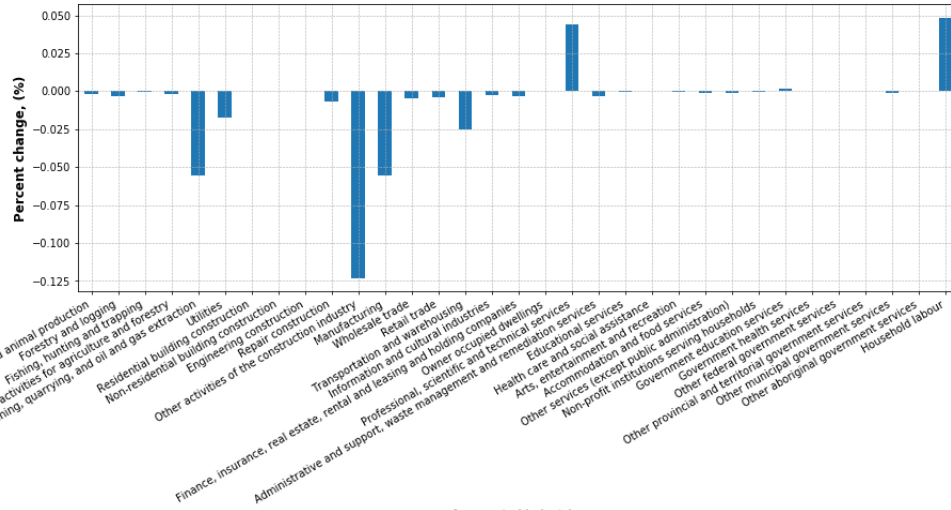


**Domain of negative change in energy use in RoW:  
adaptive reuse of  
Residential building construction industry**

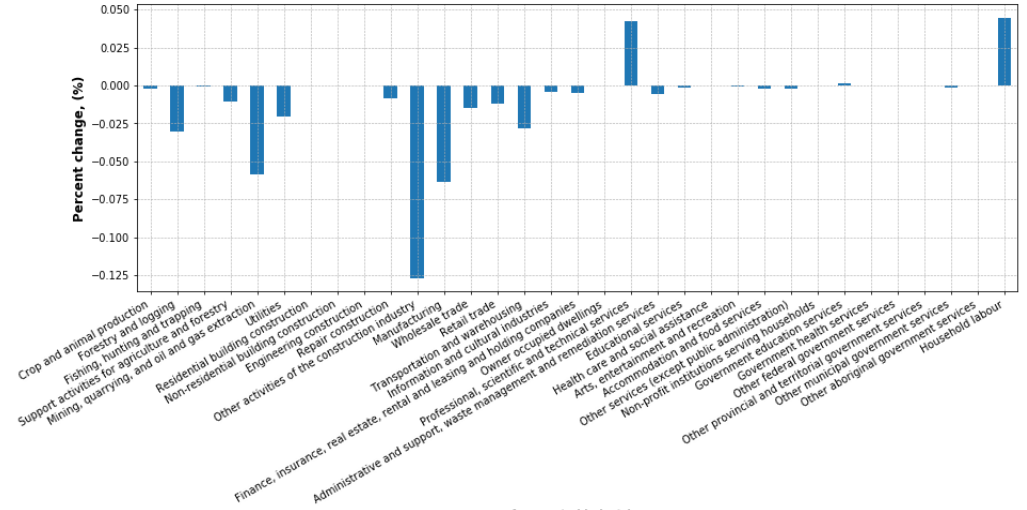


# Appendix H – Plots of changes to output at aggregated level for each scenario

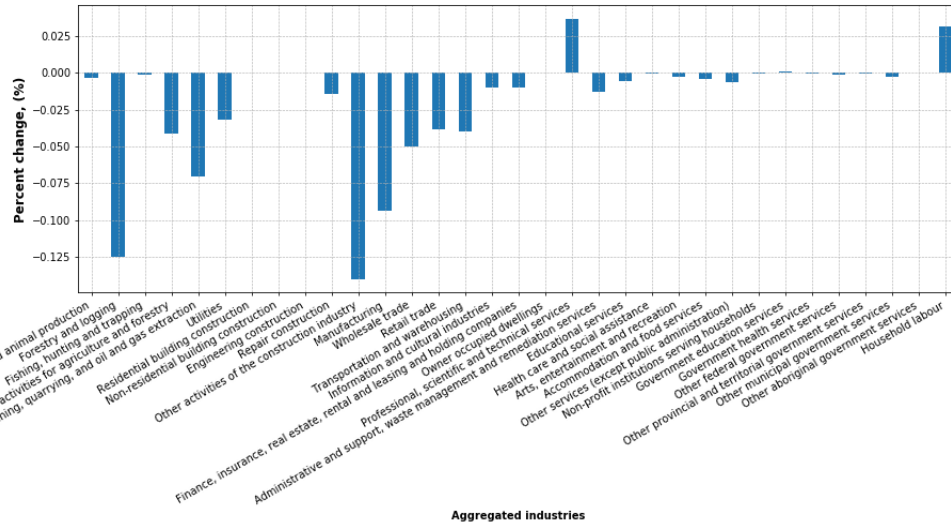
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'Basic' scenario**



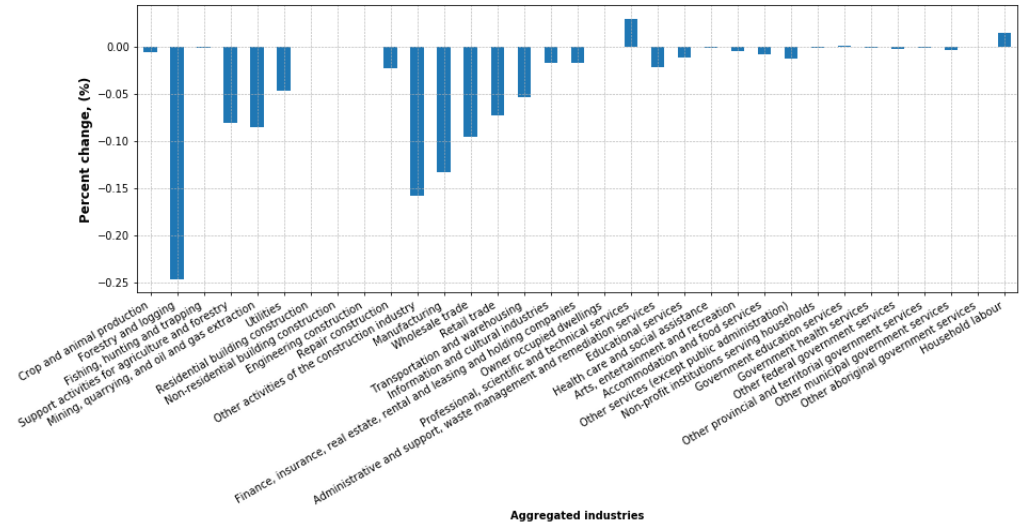
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'10%' scenario**



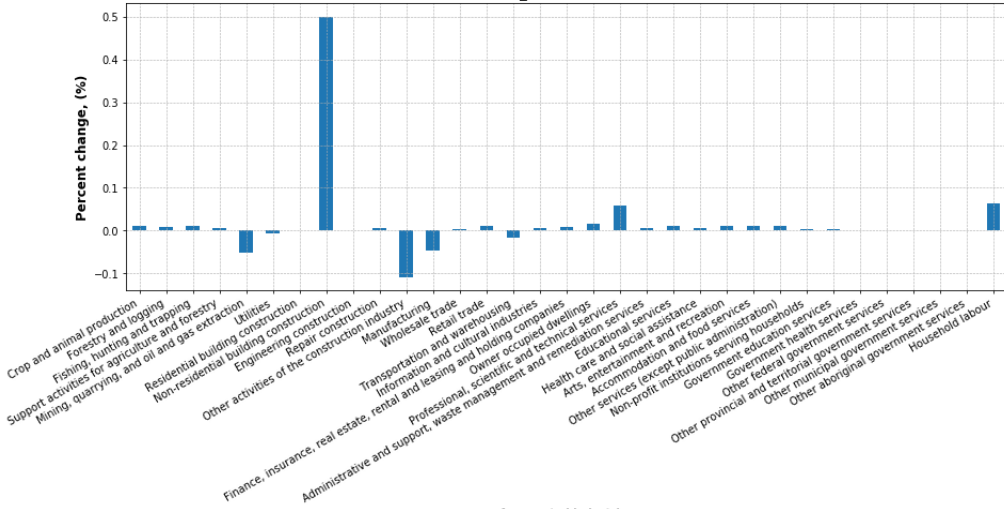
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'45%' scenario**



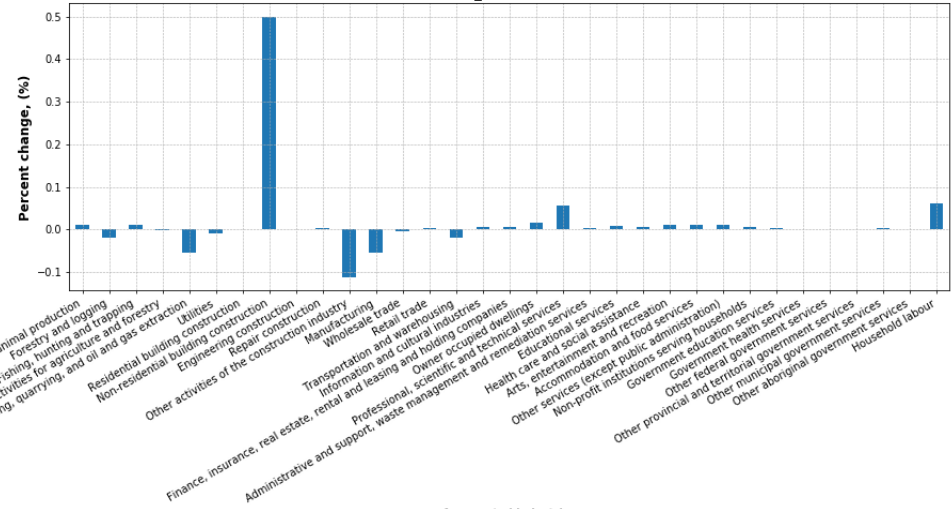
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'90%' scenario**



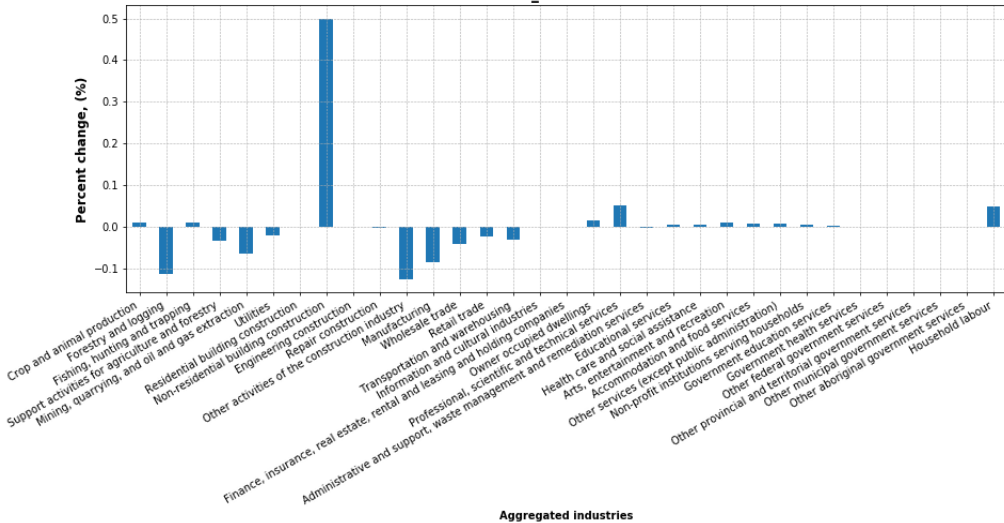
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_basic' scenario**



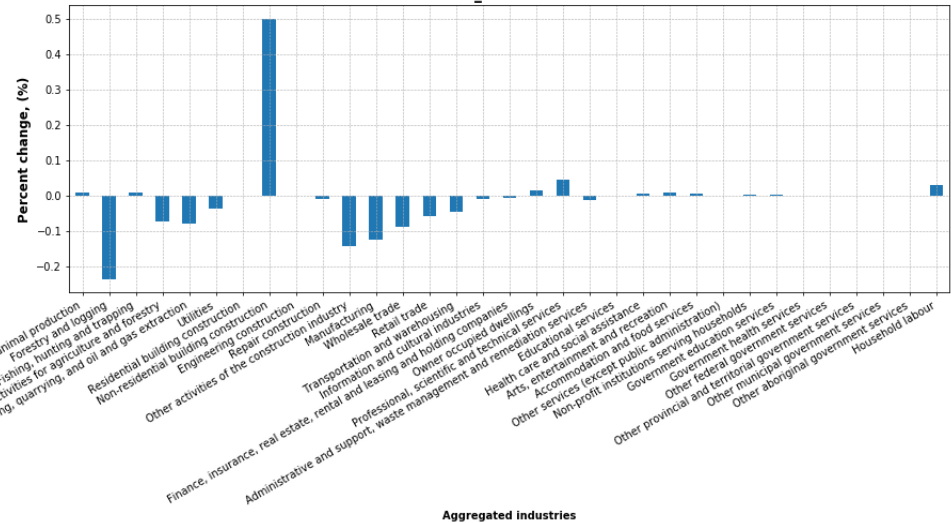
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_10' scenario**



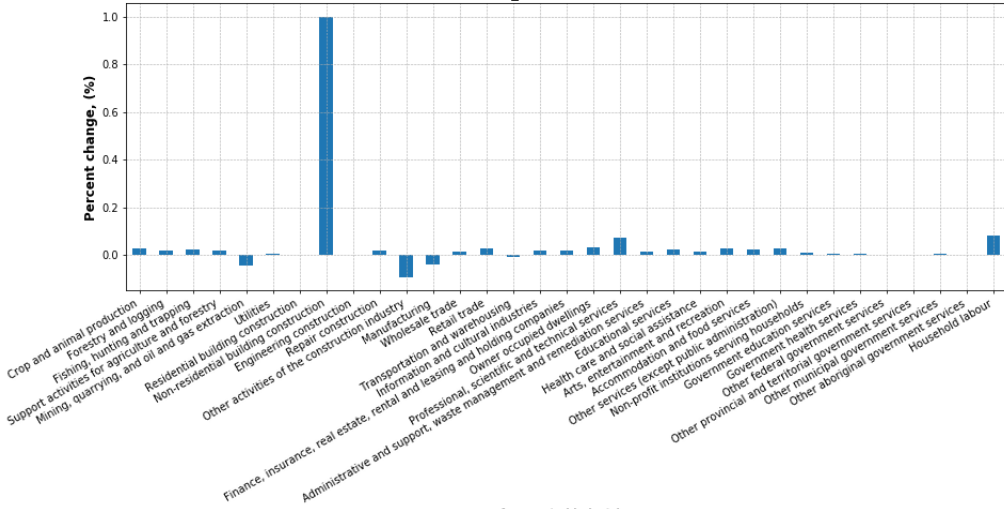
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_45' scenario**



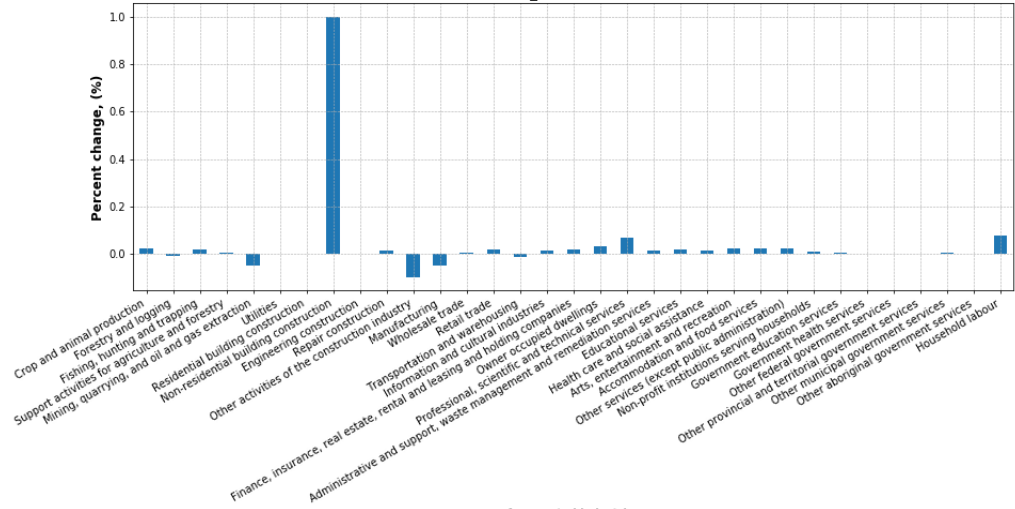
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_90' scenario**



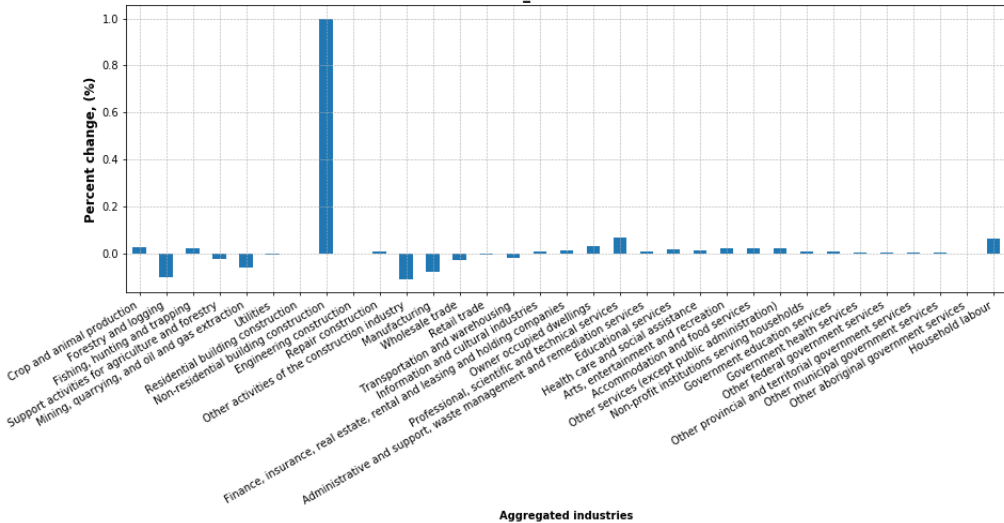
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_basic' scenario**



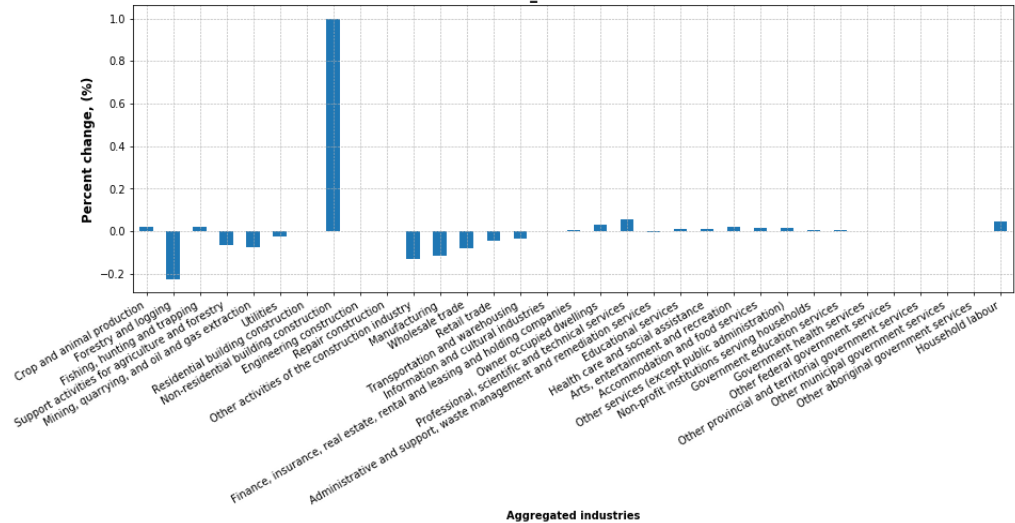
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_10' scenario**



**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_45' scenario**

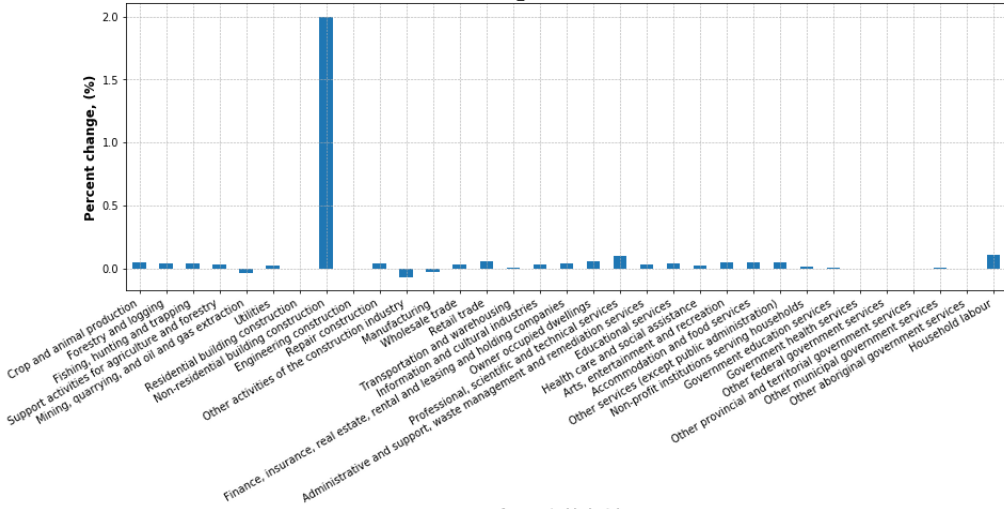


**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_90' scenario**

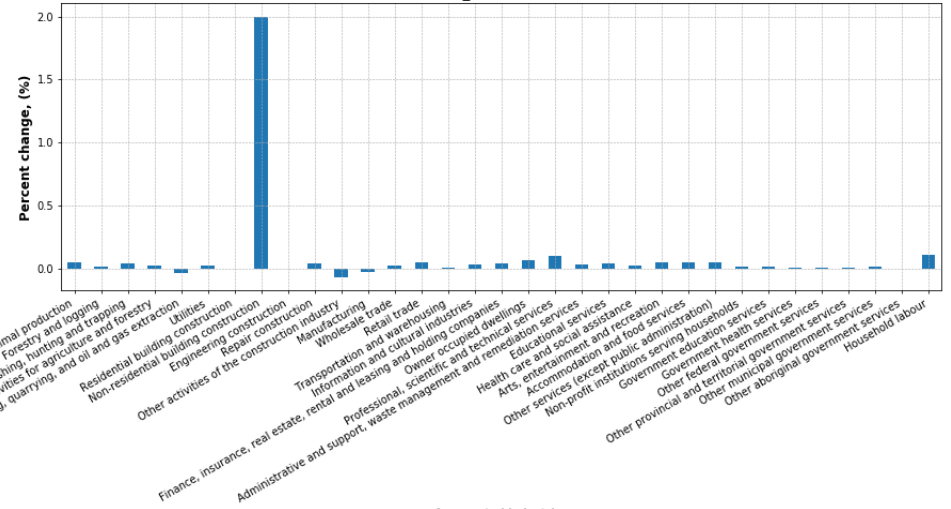




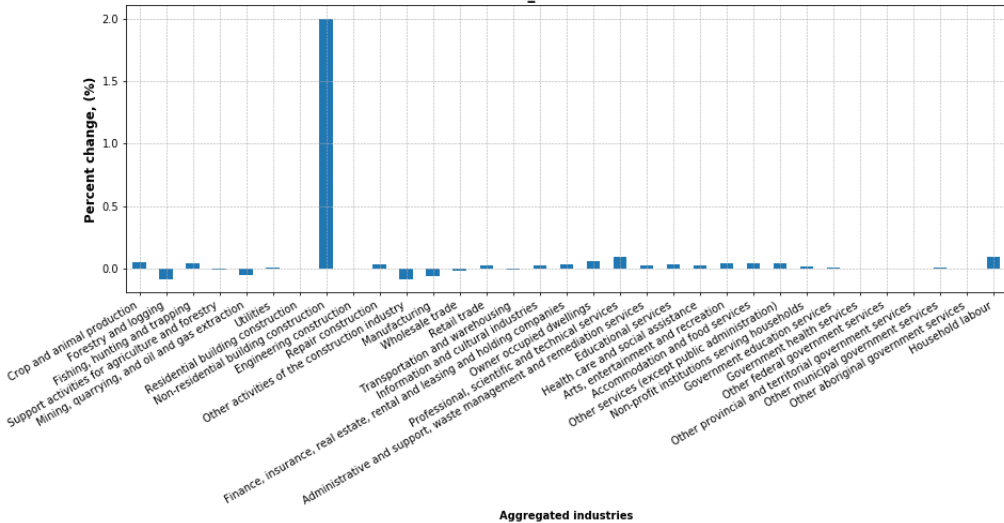
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_basic' scenario**



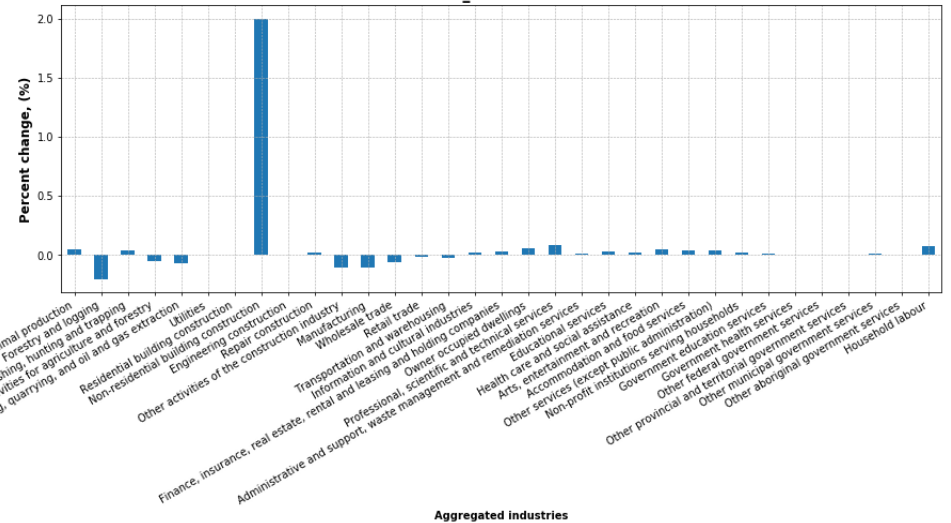
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_10' scenario**



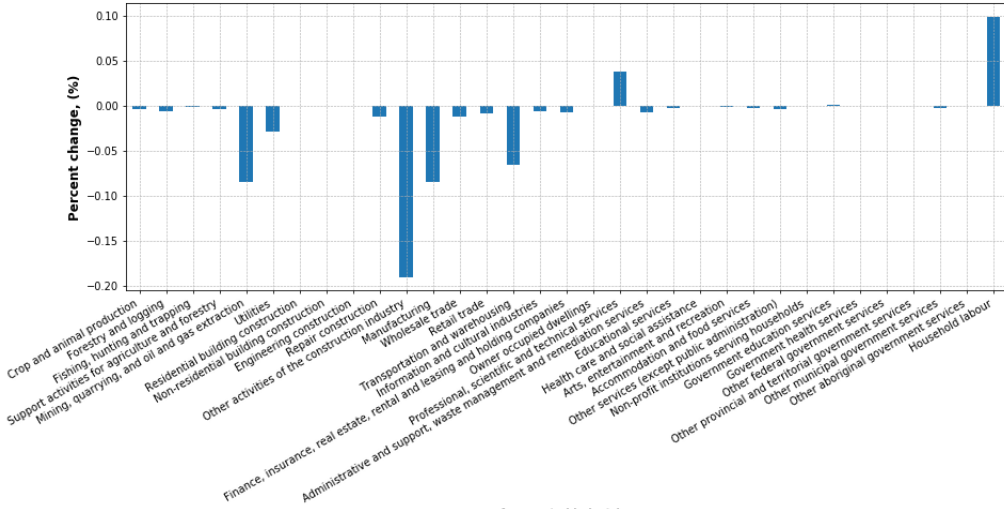
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_45' scenario**



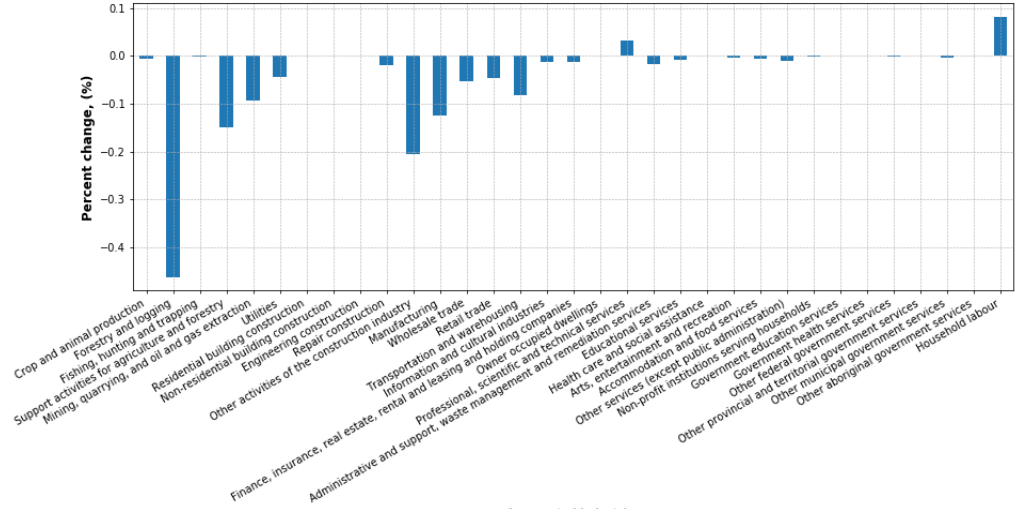
**Ontario Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_90' scenario**



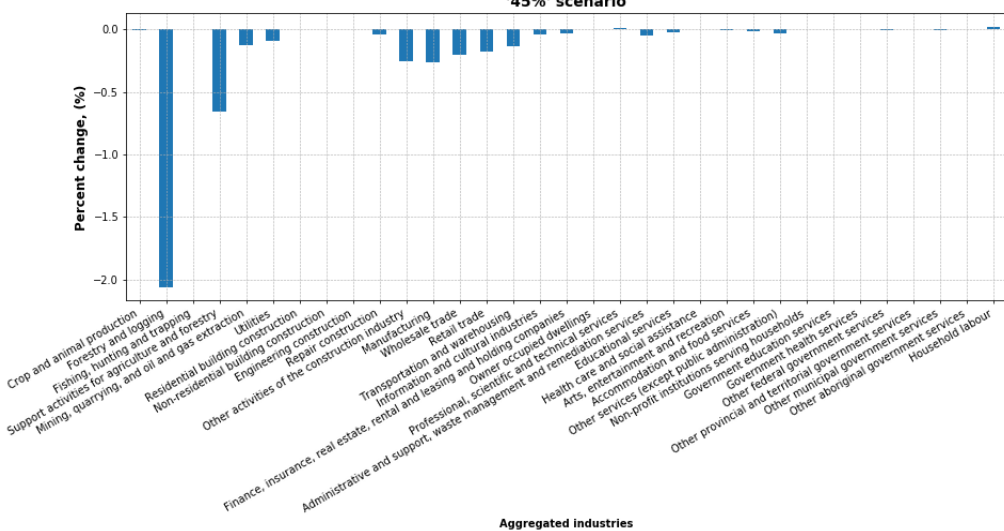
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'Basic' scenario**



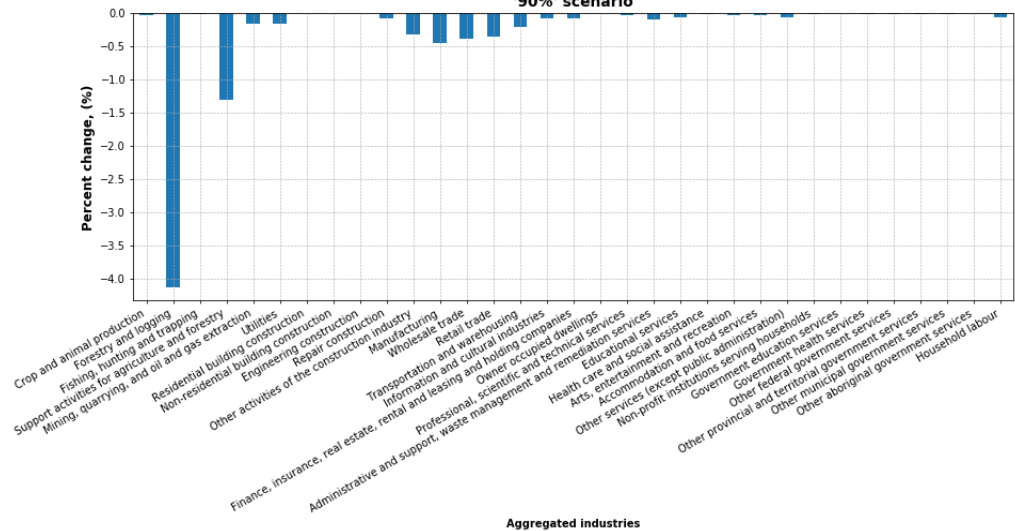
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'10%' scenario**



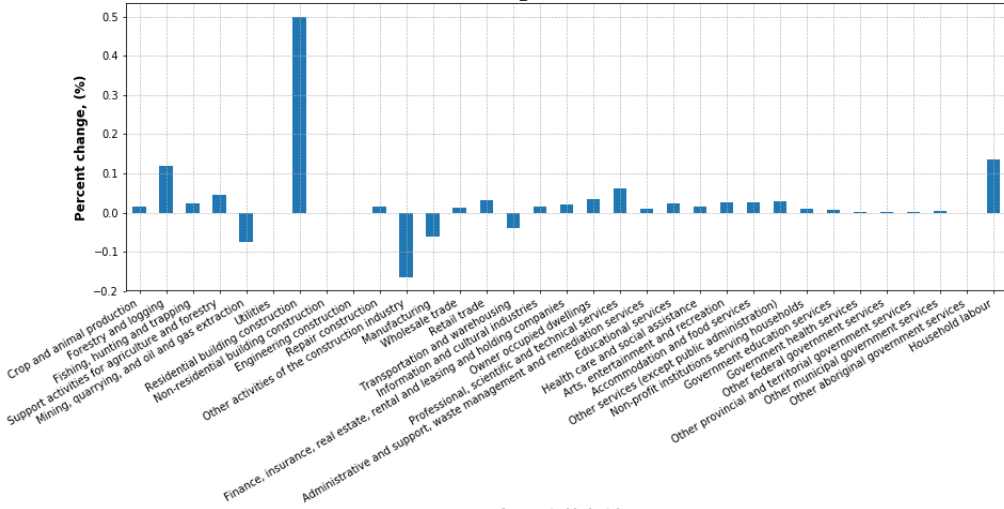
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'45%' scenario**



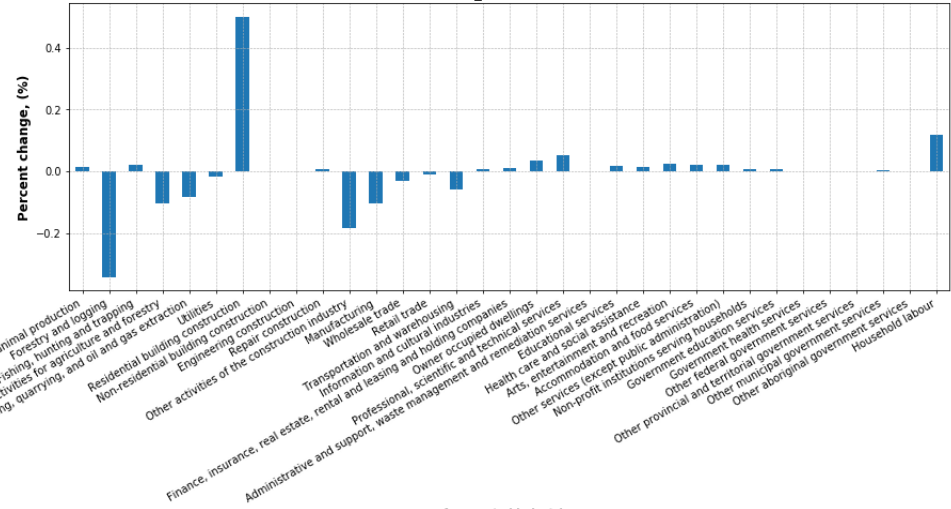
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'90%' scenario**



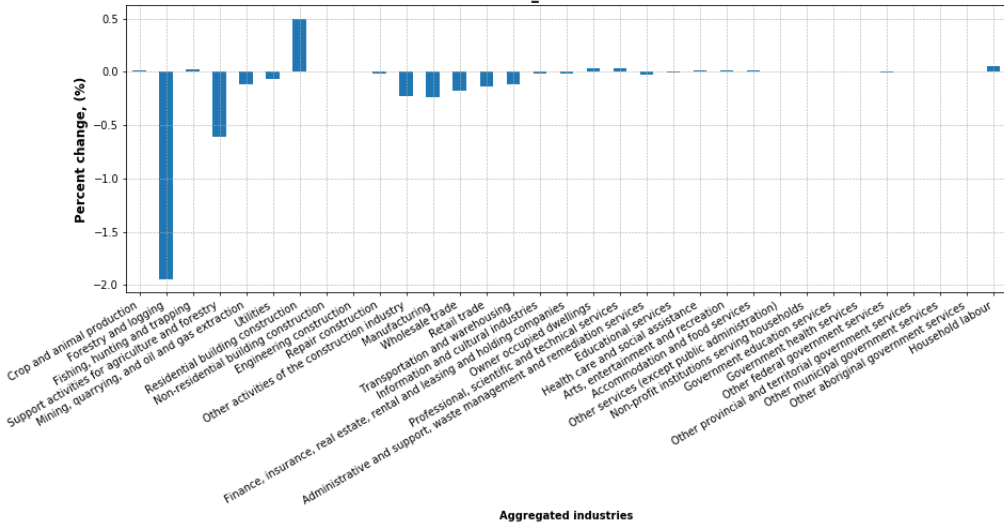
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f2.5\_basic' scenario**



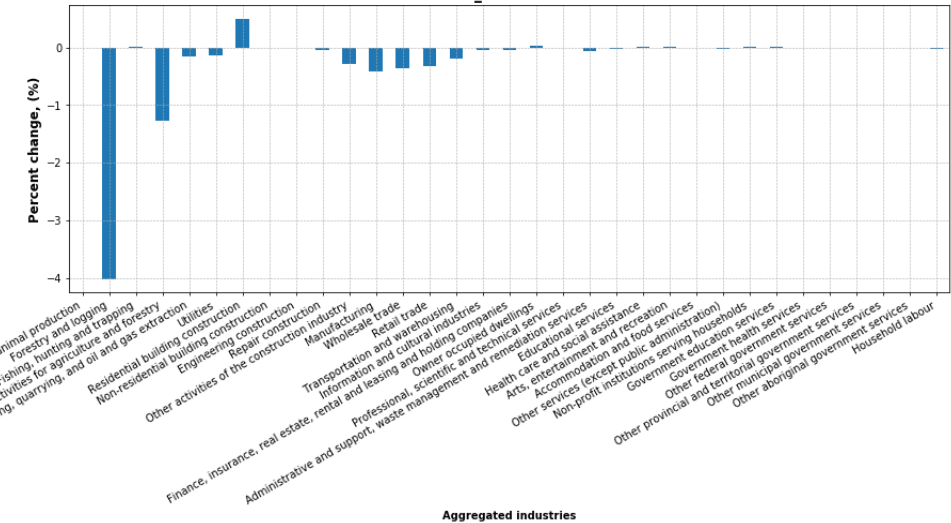
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'f2.5\_10' scenario**



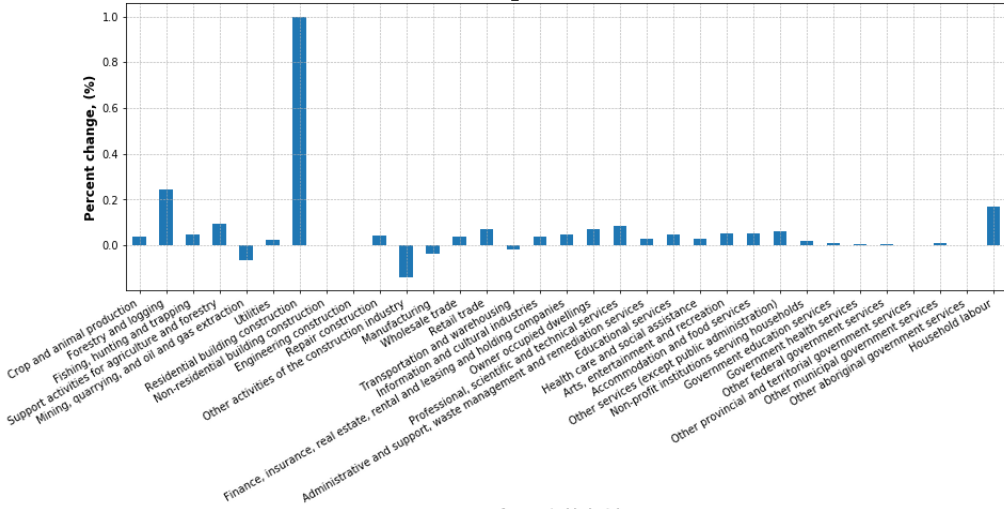
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'f2.5\_45' scenario**



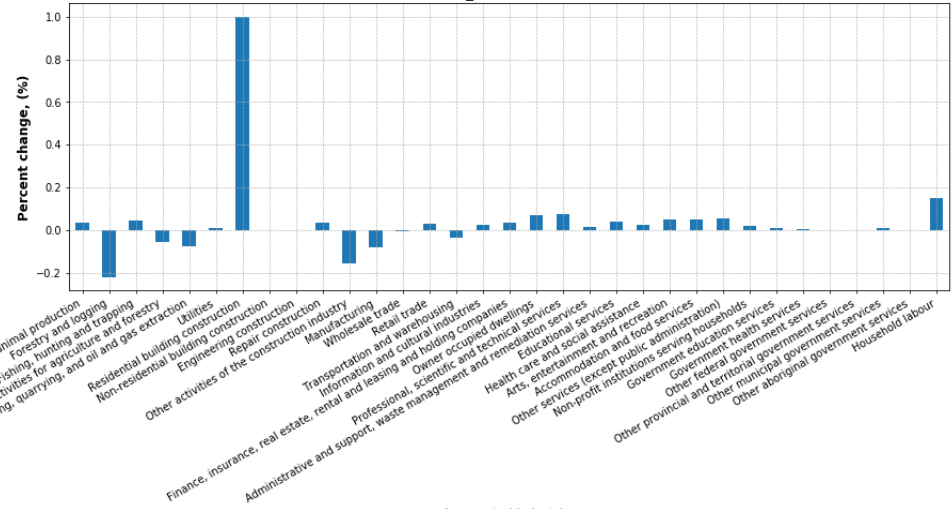
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f2.5\_90' scenario**



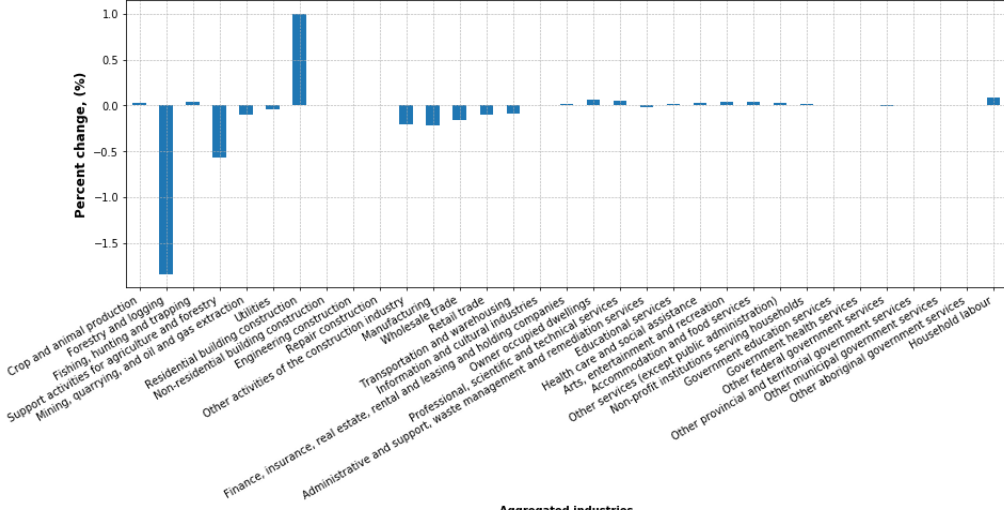
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f5\_basic' scenario**



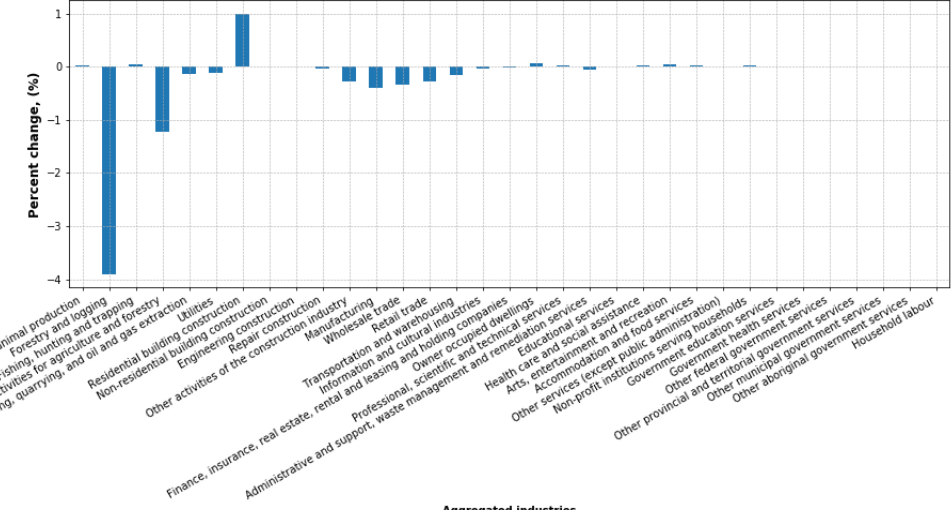
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f5\_10' scenario**



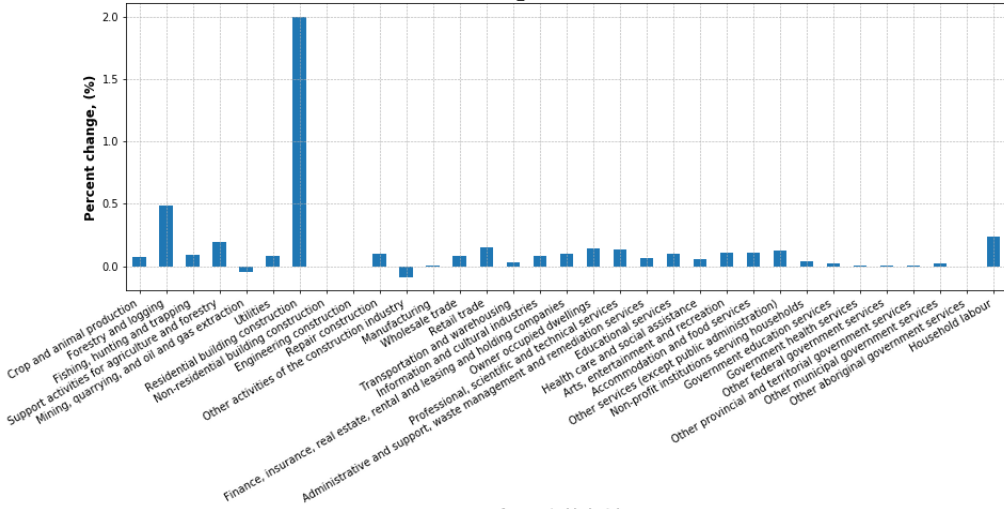
**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f5\_45' scenario**



**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f5\_90' scenario**

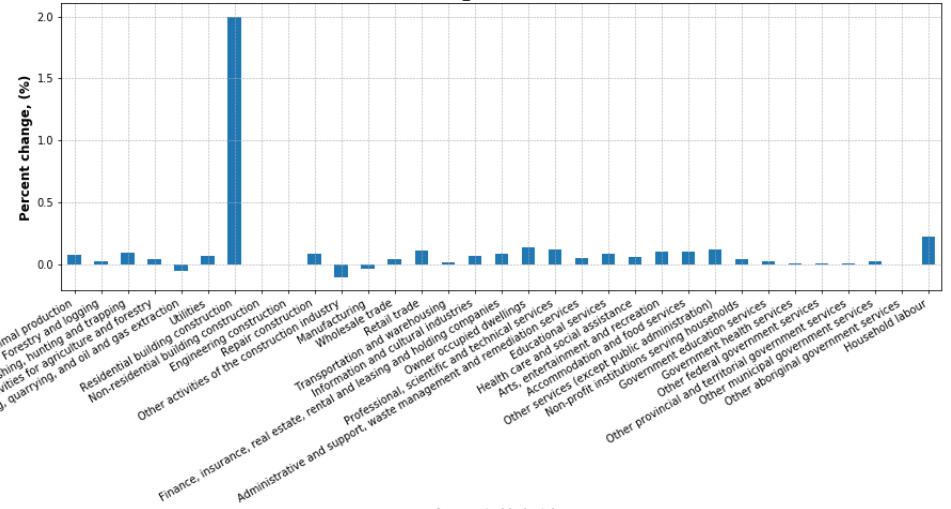


**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f10\_basic' scenario**



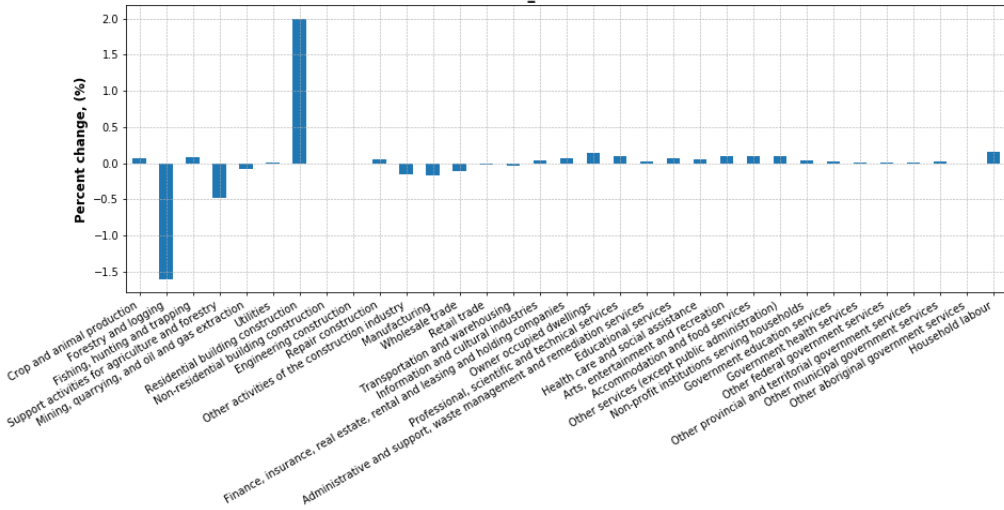
Aggregated industries

**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f10\_10' scenario**



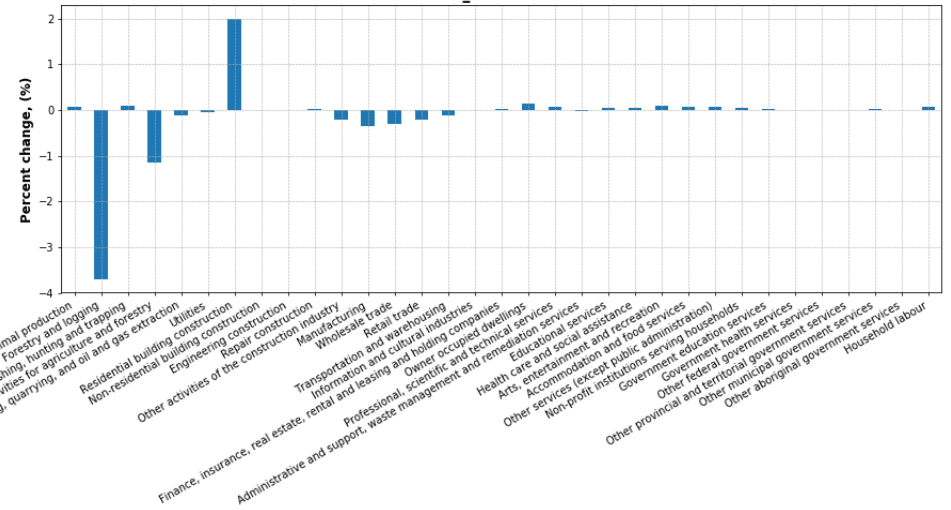
Aggregated industries

**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f10\_45' scenario**



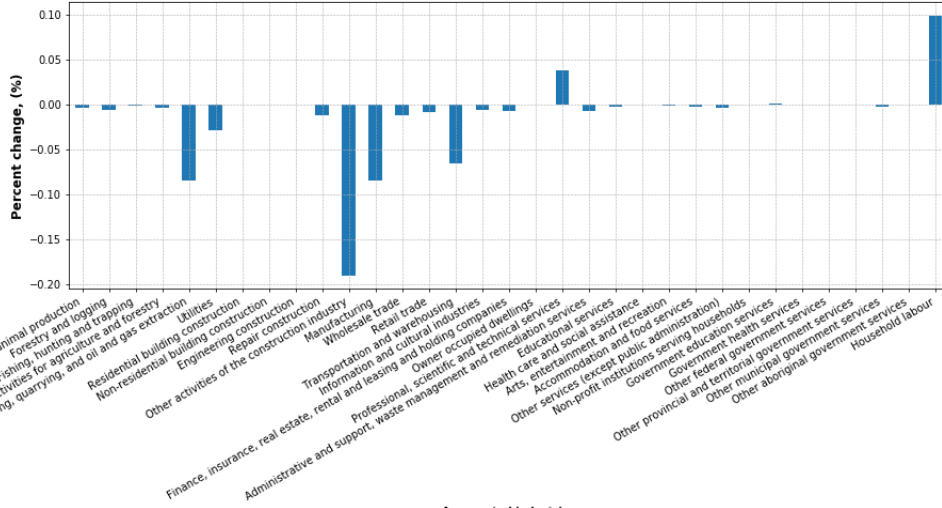
Aggregated industries

**Ontario Residential building construction :  
Changes in output for aggregated industries  
'f10\_90' scenario**



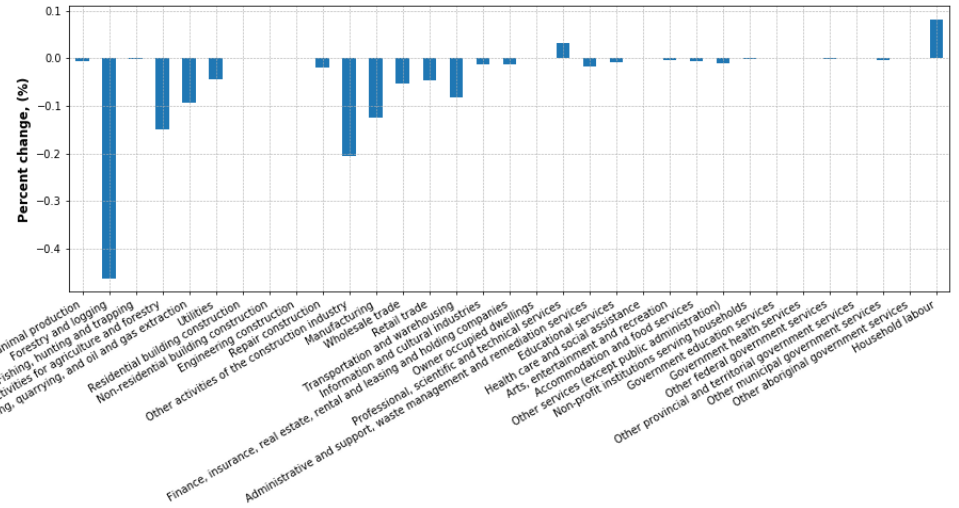
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'Basic' scenario**



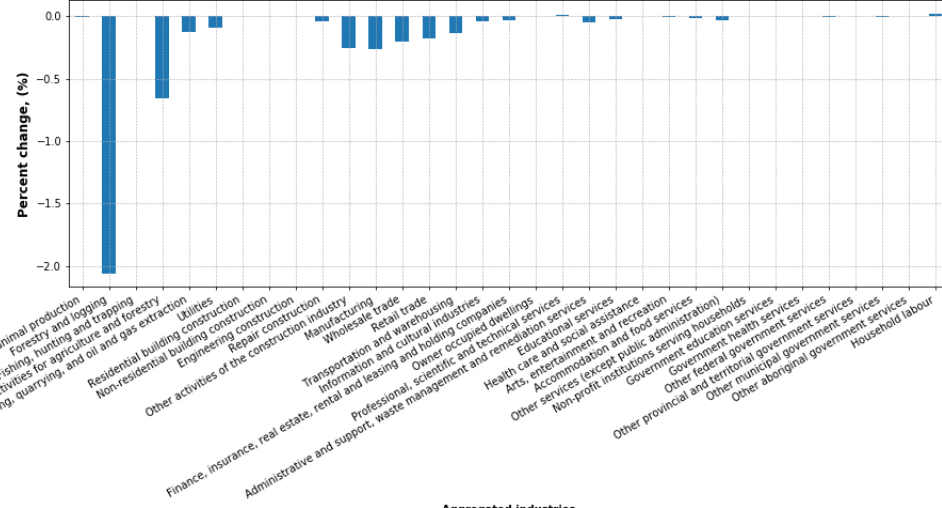
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'10%' scenario**



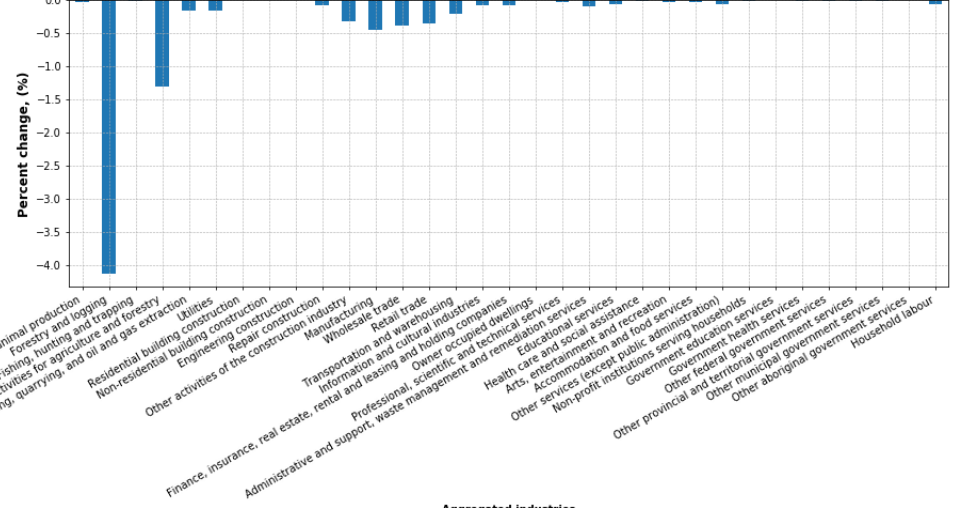
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'45%' scenario**



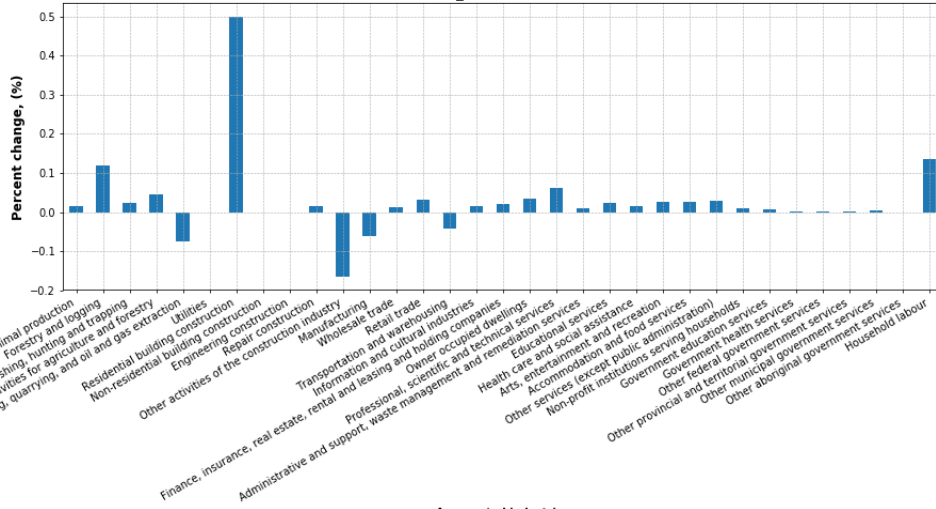
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'90%' scenario**



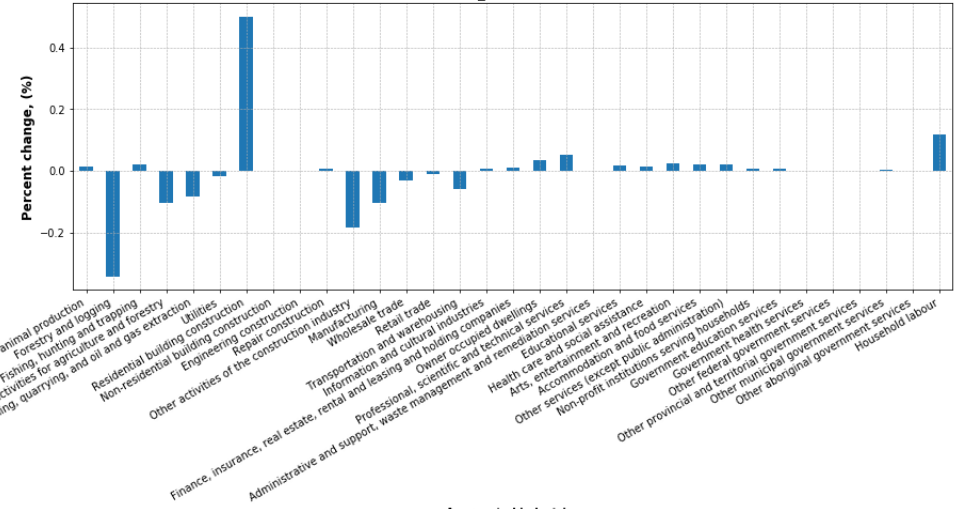
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f2.5\_basic' scenario**



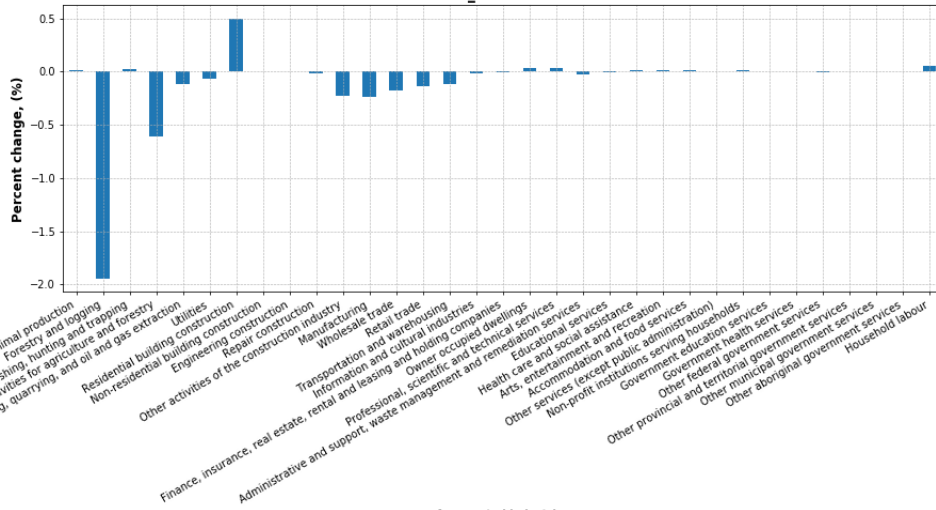
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f2.5\_10' scenario**



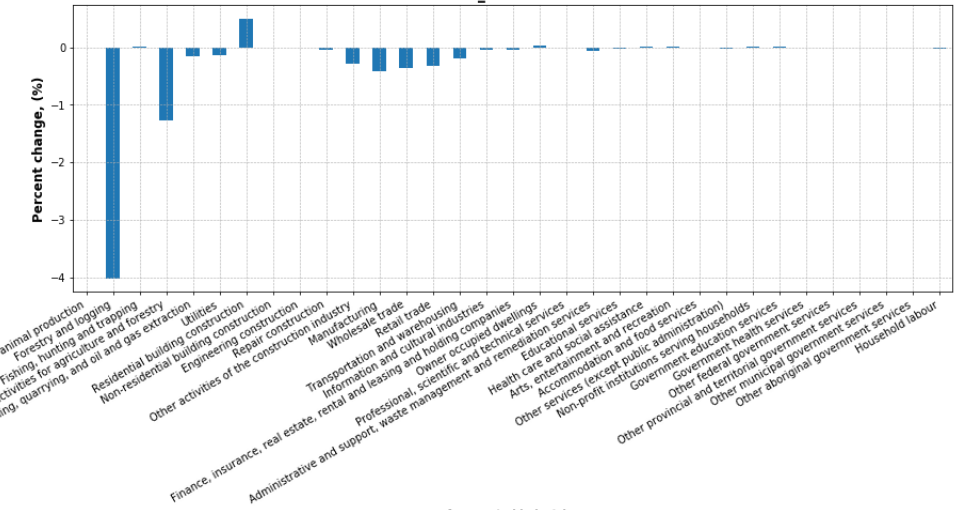
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f2.5\_45' scenario**



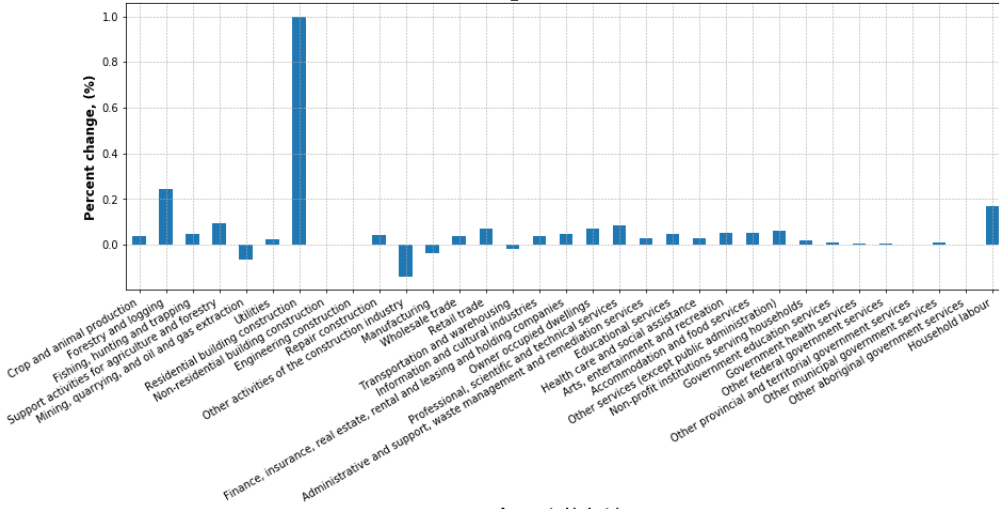
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f2.5\_90' scenario**



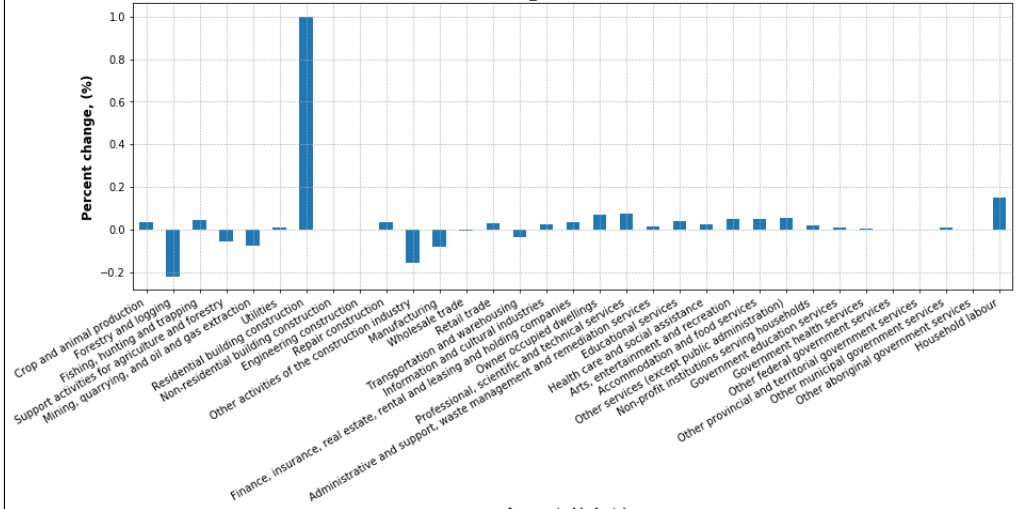
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f5\_basic' scenario**



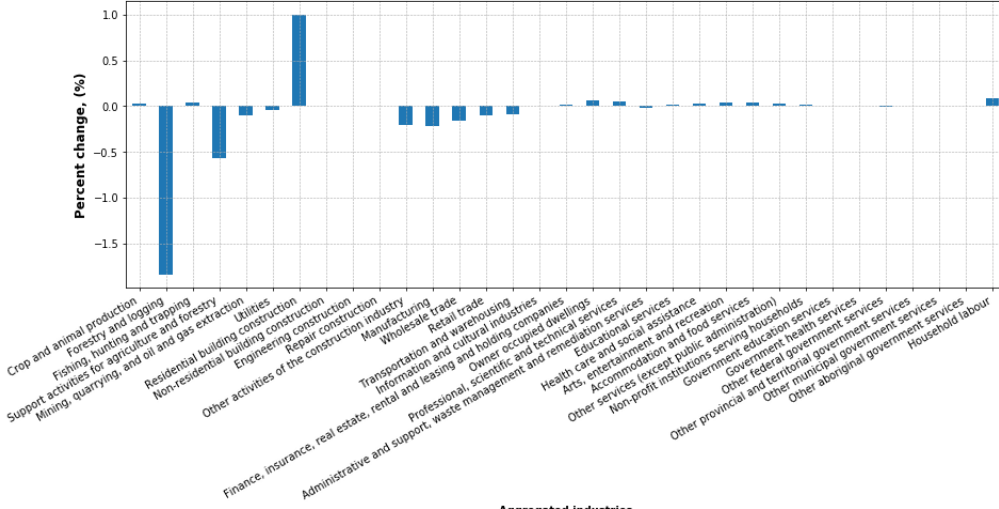
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f5\_10' scenario**



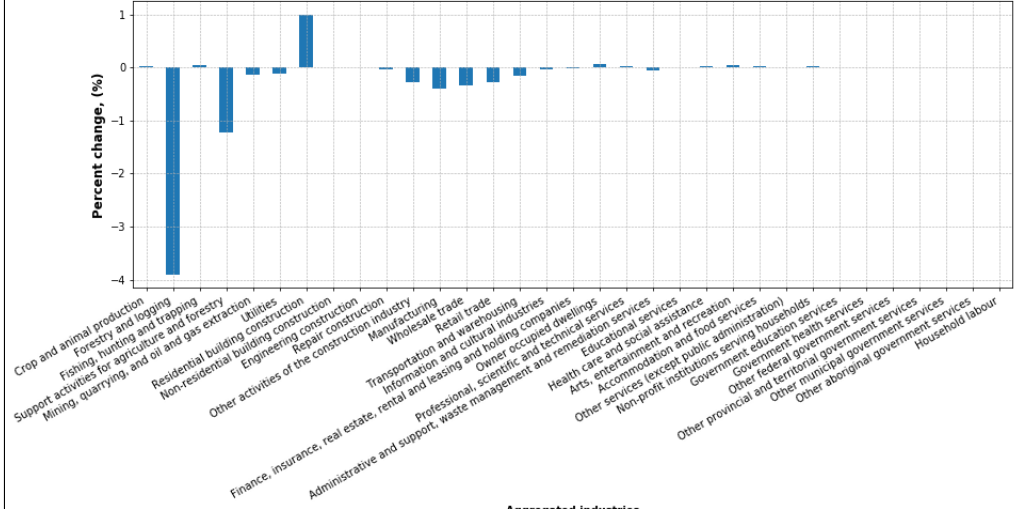
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f5\_45' scenario**



Aggregated industries

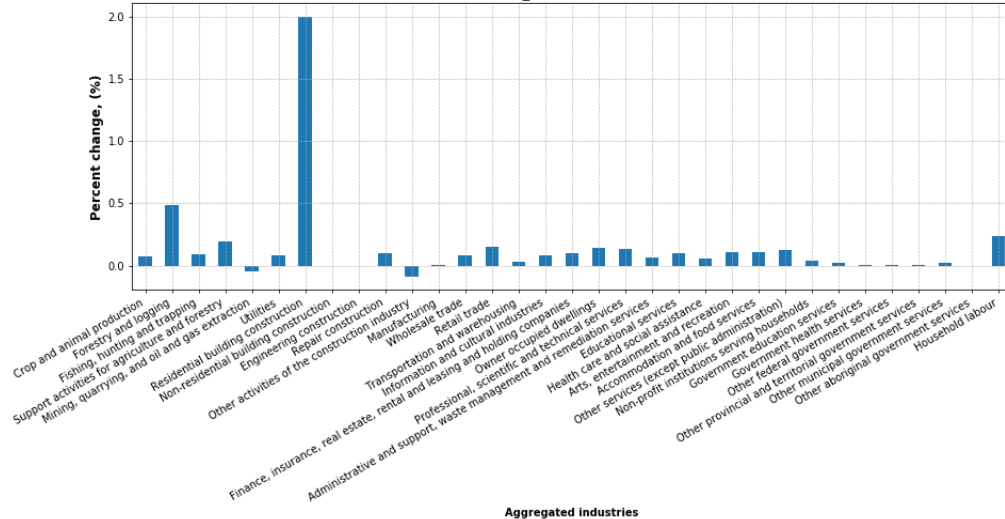
**RoW Residential building construction :  
Changes in output for aggregated industries  
'f5\_90' scenario**



Aggregated industries

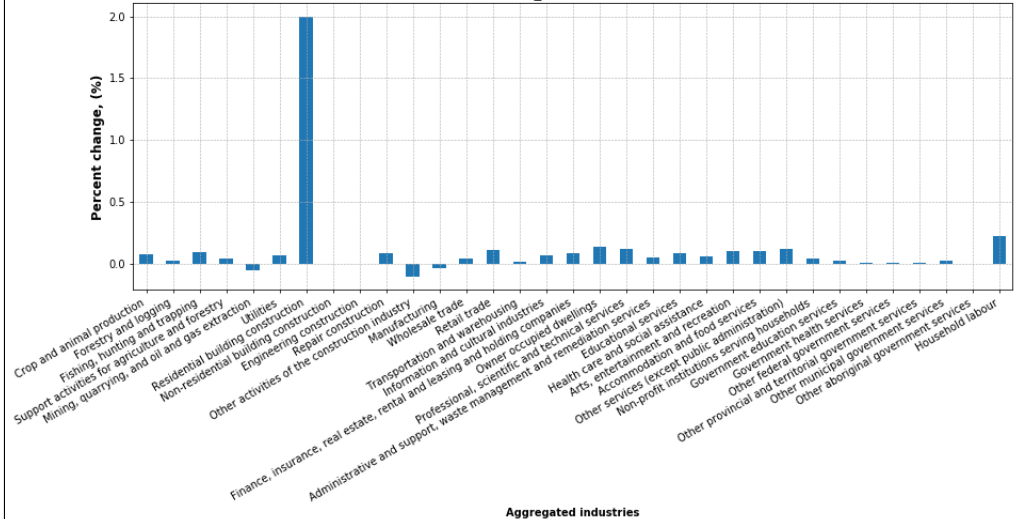


**RoW Residential building construction :  
Changes in output for aggregated industries  
'f10\_basic' scenario**



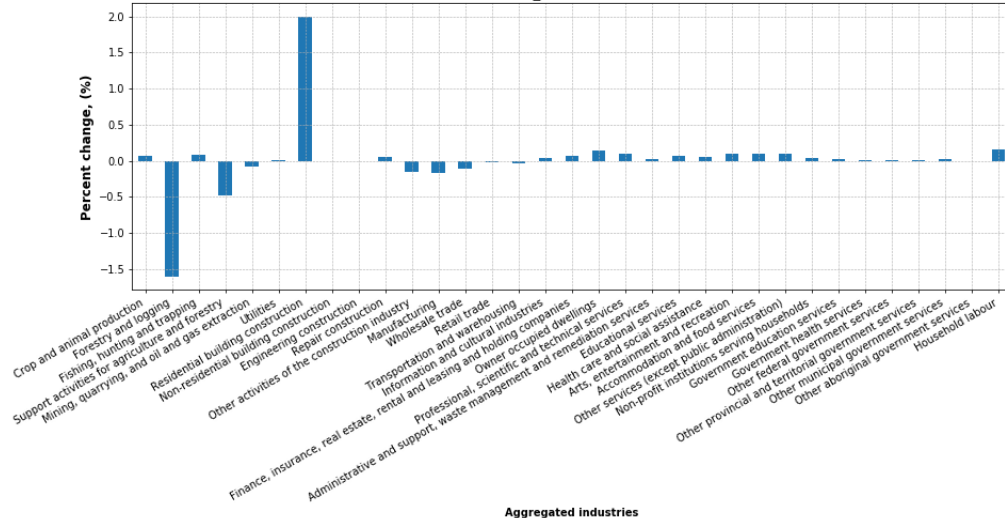
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f10\_10' scenario**



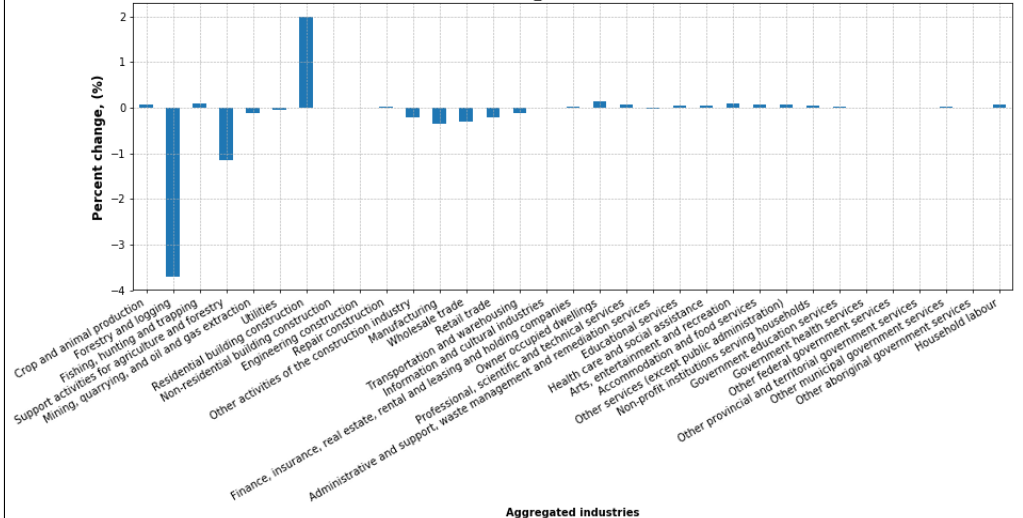
Aggregated industries

**RoW Residential building construction :  
Changes in output for aggregated industries  
'f10\_45' scenario**



Aggregated industries

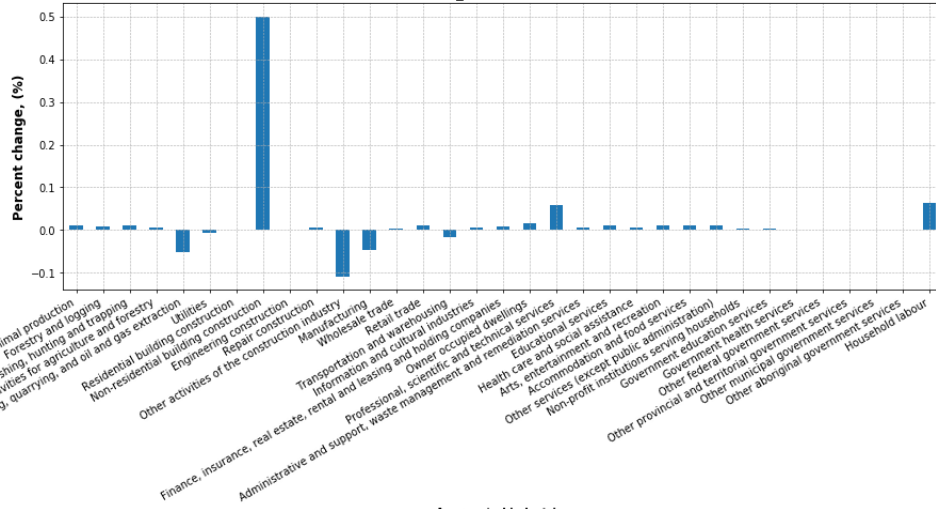
**RoW Residential building construction :  
Changes in output for aggregated industries  
'f10\_90' scenario**



Aggregated industries

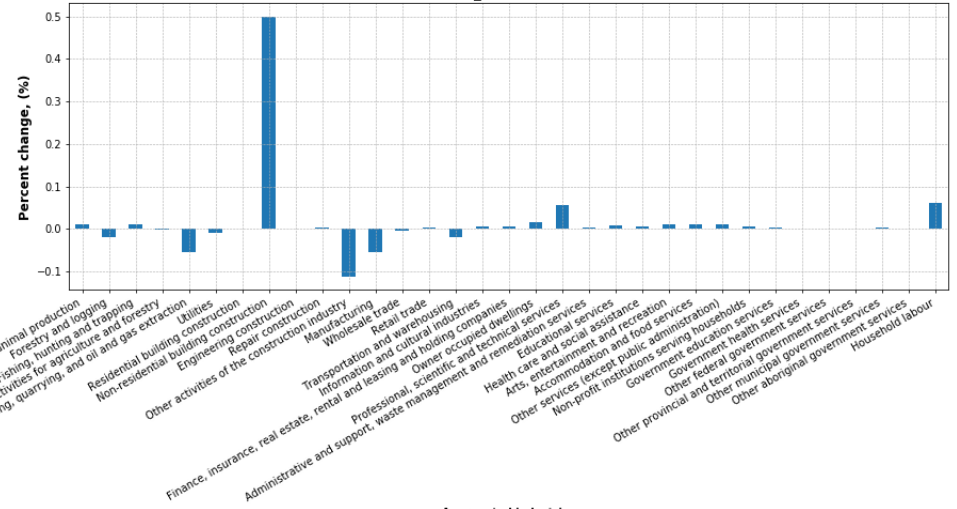


**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_basic' scenario**



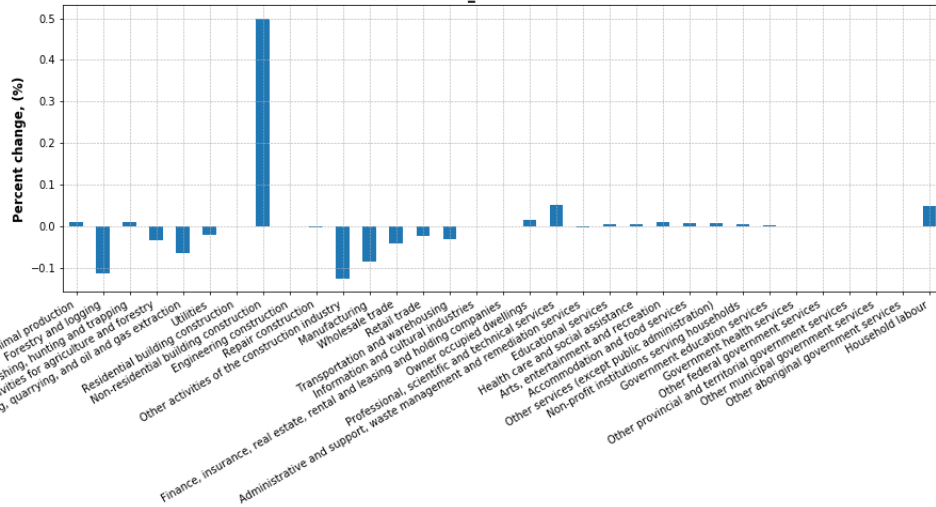
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_10' scenario**



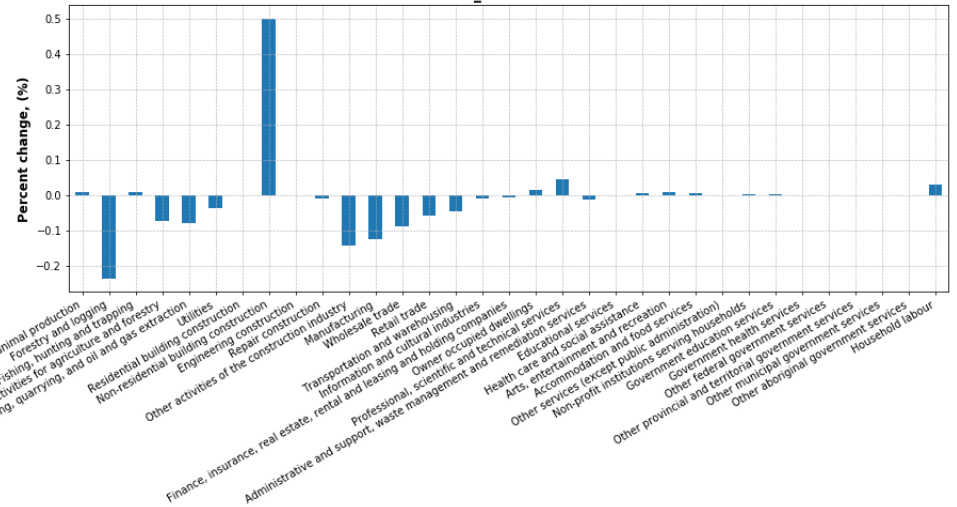
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_45' scenario**



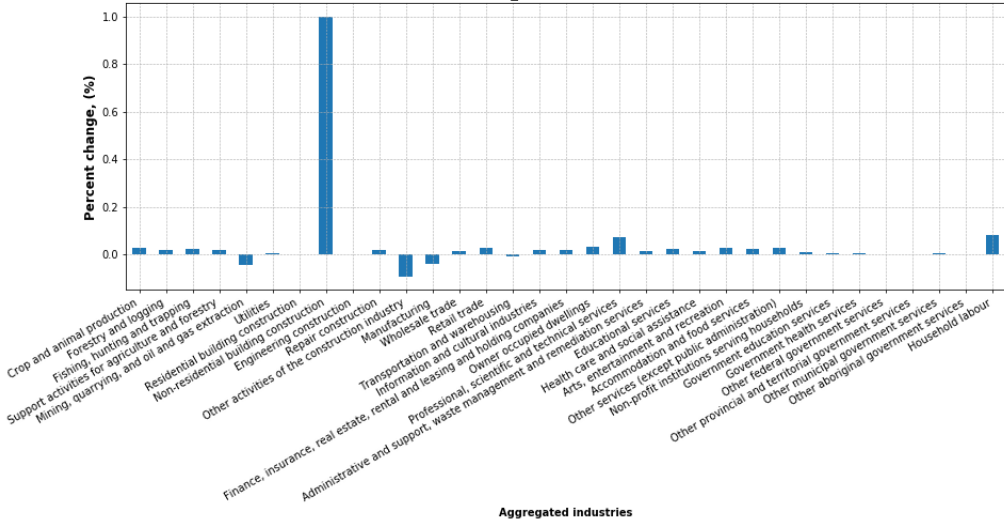
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f2.5\_90' scenario**



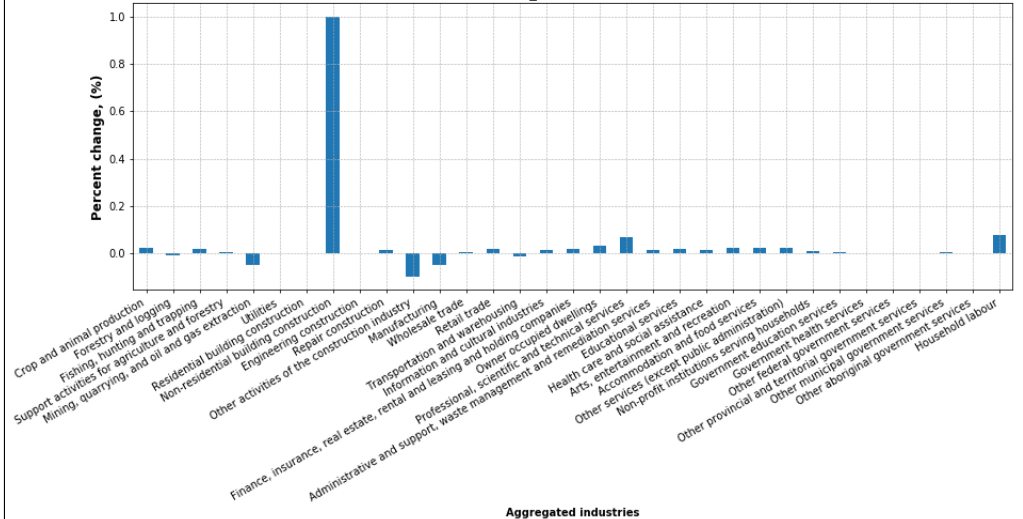
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_basic' scenario**



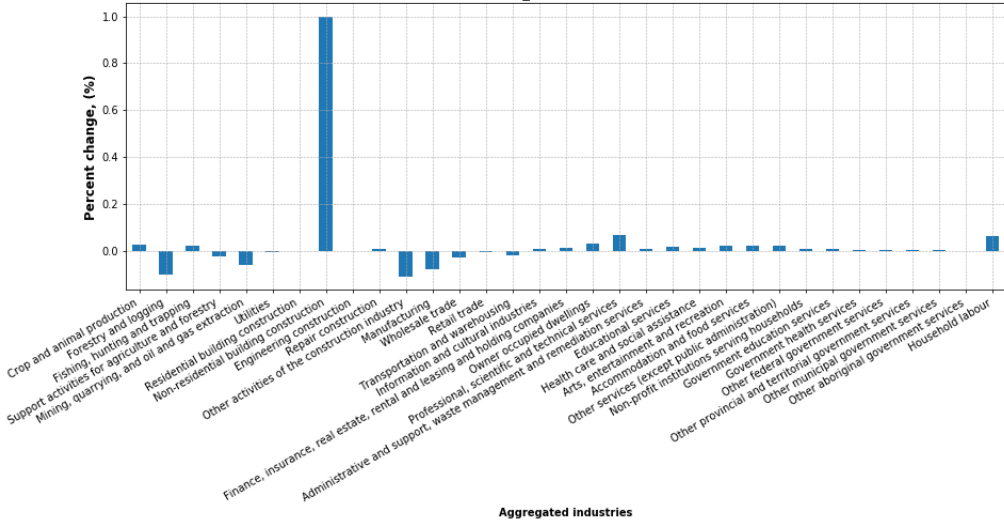
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_10' scenario**



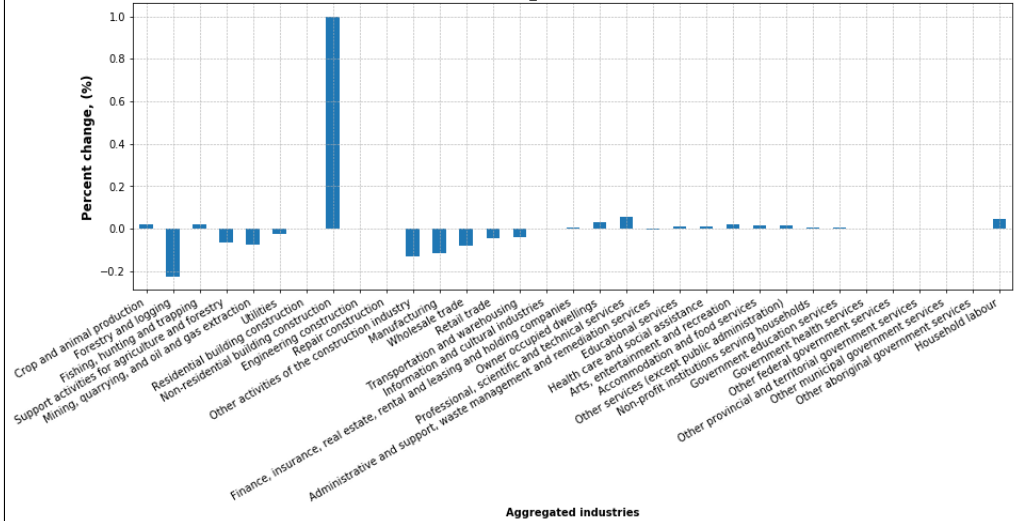
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_45' scenario**



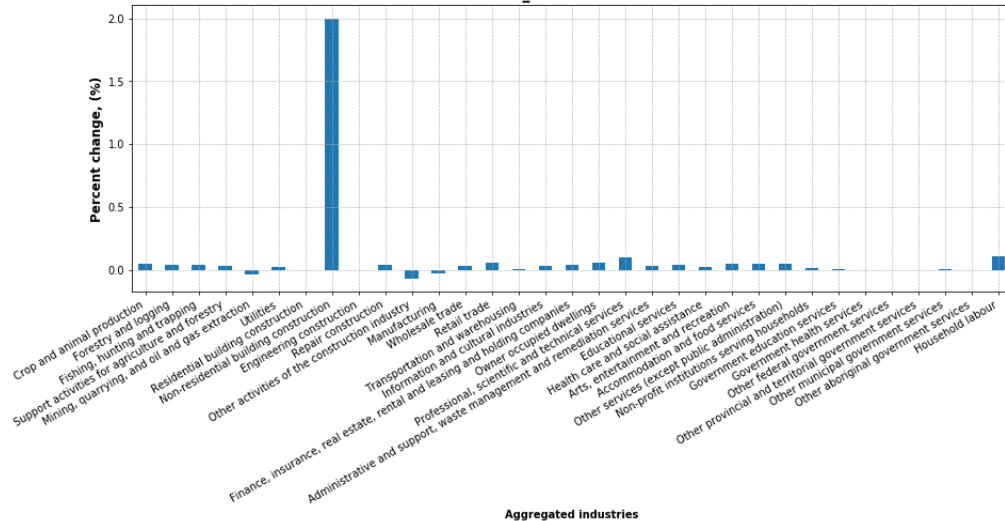
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f5\_90' scenario**



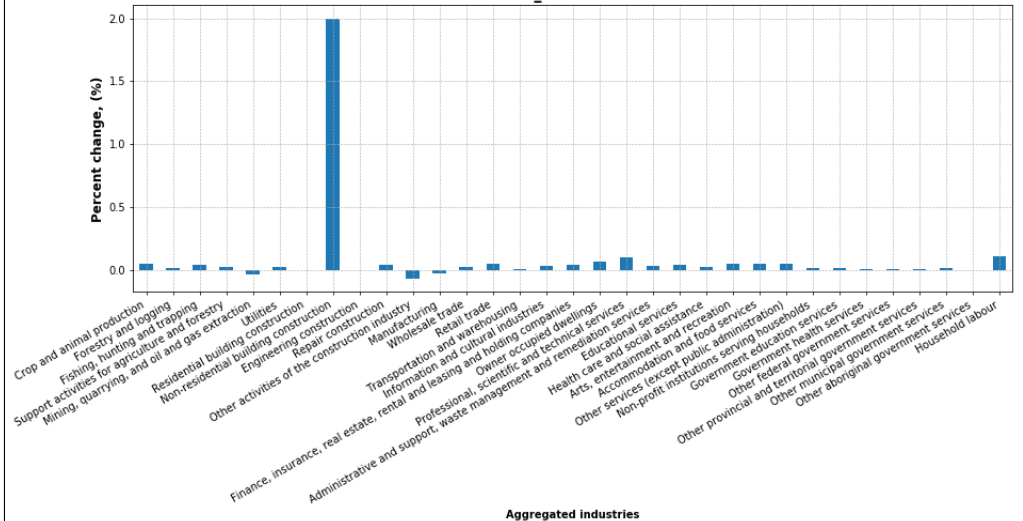
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_basic' scenario**



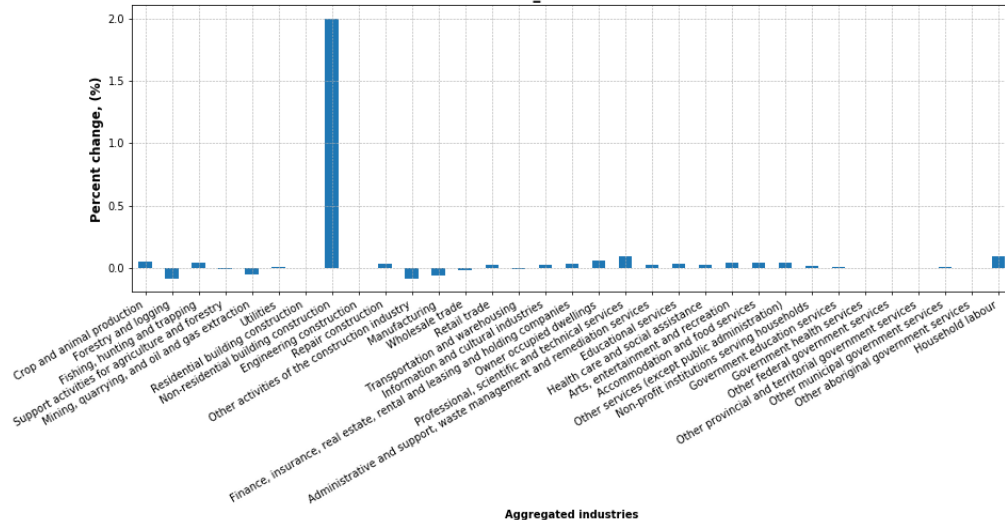
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_10' scenario**



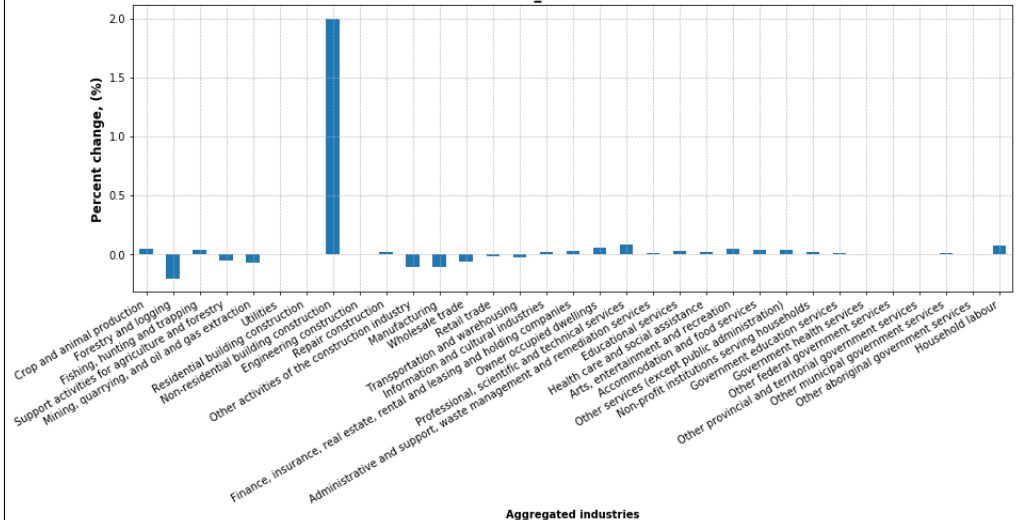
Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_45' scenario**



Aggregated industries

**RoW Non-residential building construction :  
Changes in output for aggregated industries  
'f10\_90' scenario**



Aggregated industries

## Appendix I – Top 10 industry output decreases and increases for all scenarios

### Ontario 'Basic' Scenario

#### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.76	Cement and concrete product manufacturing	-91594.40	-2.47
2	Architectural and structural metals manufacturing	-64379.35	-1.30	Architectural and structural metals manufacturing	-45022.52	-0.91
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-5488.28	-1.07	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3599.30	-0.70
4	Stone mining and quarrying	-2807.90	-0.38	Stone mining and quarrying	-1842.25	-0.25
5	Forging and stamping	-3675.65	-0.36	Forging and stamping	-1950.57	-0.19
6	Cutlery, hand tools and other fabricated metal product manufacturing	-7226.64	-0.26	Boiler, tank and shipping container manufacturing	-1999.34	-0.13
7	Other activities of the construction industry	-2542.43	-0.19	Other activities of the construction industry	-1643.67	-0.12
8	Boiler, tank and shipping container manufacturing	-2914.55	-0.19	Non-metallic mineral product manufacturing (except cement and concrete products)	-3450.15	-0.12
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-5023.72	-0.17	Cutlery, hand tools and other fabricated metal product manufacturing	-3002.75	-0.11
10	Machine shops, turned product, and screw, nut and bolt manufacturing	-3895.53	-0.14	Alumina and aluminum production and processing	-1877.50	-0.09

#### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	27901.48	0.29	Architectural, engineering and related services	30152.24	0.31
2	Household	378011.75	0.10	Household	184656.96	0.05
3	Food, beverage and tobacco wholesaler-distributors	1608.41	0.01	Food, beverage and tobacco wholesaler-distributors	1901.27	0.02
4	Specialized design services	78.68	0.01	Specialized design services	127.12	0.01
5	Universities	546.16	0.00	Management, scientific and technical consulting services	412.42	0.01
6	Computer systems design and related services	478.66	0.00	Computer systems design and related services	1011.83	0.00
7	Management, scientific and technical consulting services	41.59	0.00	Universities	615.93	0.00
8	Medical equipment and supplies manufacturing	7.56	0.00	Other professional, scientific and technical services	206.71	0.00
9	Other professional, scientific and technical services	11.76	0.00	Data processing, hosting, and related services	67.35	0.00
10	Private households	0.00	0.00	Medical equipment and supplies manufacturing	39.82	0.00

## Ontario '10%' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.77	Cement and concrete product manufacturing	-91743.48	-2.47
2	Architectural and structural metals manufacturing	-75427.97	-1.52	Architectural and structural metals manufacturing	-47359.48	-0.96
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-5665.85	-1.10	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3655.63	-0.71
4	Other wood product manufacturing	-17020.16	-0.96	Stone mining and quarrying	-1905.22	-0.25
5	Sawmills and wood preservation	-9507.72	-0.83	Electric lighting equipment manufacturing	-1049.56	-0.25
6	Veneer, plywood and engineered wood product manufacturing	-7790.06	-0.75	Non-metallic mineral product manufacturing (except cement and concrete products)	-7194.99	-0.25
7	Household and institutional furniture and kitchen cabinet manufacturing	-11749.40	-0.59	Forging and stamping	-2512.41	-0.25
8	Forging and stamping	-5603.93	-0.55	Boiler, tank and shipping container manufacturing	-3016.10	-0.19
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-13770.82	-0.48	Spring and wire product manufacturing	-622.14	-0.17
10	Forestry and logging	-4812.55	-0.46	Cutlery, hand tools and other fabricated metal product manufacturing	-4465.73	-0.16

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	27377.16	0.28	Architectural, engineering and related services	30046.59	0.31
2	Household	312031.52	0.08	Household	170638.53	0.04
3	Food, beverage and tobacco wholesaler-distributors	1243.68	0.01	Food, beverage and tobacco wholesaler-distributors	1818.81	0.02
4	Universities	488.24	0.00	Specialized design services	88.04	0.01
5	Private households	0.00	0.00	Computer systems design and related services	833.75	0.00
6	Owner-occupied dwellings	0.00	0.00	Universities	603.60	0.00
7	Other educational services	0.00	0.00	Management, scientific and technical consulting services	255.87	0.00
8	Oil and gas engineering construction	0.00	0.00	Other professional, scientific and technical services	119.85	0.00
9	Non-residential building construction	0.00	0.00	Professional and similar organizations	32.33	0.00
10	Residential building construction	0.00	0.00	Medical equipment and supplies manufacturing	23.06	0.00

## Ontario '45%' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-74950.36	-4.23	Cement and concrete product manufacturing	-92265.27	-2.49
2	Cement and concrete product manufacturing	-141461.70	-3.81	Architectural and structural metals manufacturing	-55538.84	-1.12
3	Sawmills and wood preservation	-42475.92	-3.71	Electric lighting equipment manufacturing	-4429.91	-1.07
4	Veneer, plywood and engineered wood product manufacturing	-34908.68	-3.36	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3852.80	-0.75
5	Household and institutional furniture and kitchen cabinet manufacturing	-52726.48	-2.66	Non-metallic mineral product manufacturing (except cement and concrete products)	-20301.90	-0.70
6	Architectural and structural metals manufacturing	-114098.11	-2.30	Spring and wire product manufacturing	-2151.66	-0.59
7	Forestry and logging	-21440.51	-2.06	Forging and stamping	-4478.85	-0.44
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-20208.81	-1.84	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-4630.67	-0.42
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-44385.68	-1.54	Boiler, tank and shipping container manufacturing	-6574.77	-0.42
10	Building material and garden equipment and supplies dealers	-59027.77	-1.46	Machine shops, turned product, and screw, nut and bolt manufacturing	-11603.46	-0.41

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	25542.01	0.26	Architectural, engineering and related services	29676.79	0.30
2	Household	81100.70	0.02	Household	121574.01	0.03
3	Universities	285.52	0.00	Food, beverage and tobacco wholesaler-distributors	1530.20	0.01
4	Private households	0.00	0.00	Universities	560.42	0.00
5	Owner-occupied dwellings	0.00	0.00	Computer systems design and related services	210.48	0.00
6	Electric power engineering construction	0.00	0.00	Private households	0.00	0.00
7	Non-residential building construction	0.00	0.00	Owner-occupied dwellings	0.00	0.00
8	Transportation engineering construction	0.00	0.00	Communication engineering construction	0.00	0.00
9	Other educational services	0.00	0.00	Transportation engineering construction	0.00	0.00
10	Oil and gas engineering construction	0.00	0.00	Oil and gas engineering construction	0.00	0.00



## Ontario '90%' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-	-8.43	Cement and concrete product manufacturing	-92936.14	-2.50
2	Sawmills and wood preservation	-84863.61	-7.42	Electric lighting equipment manufacturing	-8776.06	-2.11
3	Veneer, plywood and engineered wood product manufacturing	-69775.48	-6.72	Architectural and structural metals manufacturing	-66055.16	-1.33
4	Household and institutional furniture and kitchen cabinet manufacturing	-	-5.32	Non-metallic mineral product manufacturing (except cement and concrete products)	-37153.65	-1.29
5	Forestry and logging	-42819.30	-4.12	Spring and wire product manufacturing	-4118.18	-1.12
6	Cement and concrete product manufacturing	-	-3.86	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-9230.87	-0.84
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-40349.26	-3.68	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-4106.30	-0.80
8	Architectural and structural metals manufacturing	-	-3.30	Machine shops, turned product, and screw, nut and bolt manufacturing	-21124.79	-0.75
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-83747.64	-2.90	Boiler, tank and shipping container manufacturing	-11150.19	-0.71
10	Building material and garden equipment and supplies dealers	-	-2.86	Forging and stamping	-7007.13	-0.69

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	23182.54	0.24	Architectural, engineering and related services	29201.35	0.30
2	Universities	24.88	0.00	Household	58491.06	0.02
3	Private households	0.00	0.00	Food, beverage and tobacco wholesaler-distributors	1159.13	0.01
4	Owner-occupied dwellings	0.00	0.00	Universities	504.91	0.00
5	Other engineering construction	0.00	0.00	Private households	0.00	0.00
6	Other aboriginal government services	0.00	0.00	Electric power engineering construction	0.00	0.00
7	Communication engineering construction	0.00	0.00	Non-residential building construction	0.00	0.00
8	Electric power engineering construction	0.00	0.00	Transportation engineering construction	0.00	0.00
9	Oil and gas engineering construction	0.00	0.00	Oil and gas engineering construction	0.00	0.00
10	Non-residential building construction	0.00	0.00	Other educational services	0.00	0.00

## Ontario 'f2.5\_basic' Scenario

### Top 10 decreases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Cement and concrete product manufacturing	-	-3.66	Cement and concrete product manufacturing	-89123.25	-2.40
2	Architectural and structural metals manufacturing	-59686.93	-1.20	Architectural and structural metals manufacturing	-43133.17	-0.87
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-5224.04	-1.02	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3462.73	-0.67
4	Stone mining and quarrying	-2451.74	-0.33	Stone mining and quarrying	-1644.17	-0.22
5	Forging and stamping	-3035.50	-0.30	Forging and stamping	-1726.10	-0.17
6	Cutlery, hand tools and other fabricated metal product manufacturing	-5799.46	-0.21	Other activities of the construction industry	-1456.44	-0.11
7	Other activities of the construction industry	-2206.02	-0.17	Boiler, tank and shipping container manufacturing	-1636.67	-0.10
8	Boiler, tank and shipping container manufacturing	-2287.06	-0.15	Cutlery, hand tools and other fabricated metal product manufacturing	-2414.78	-0.09
9	Truck transportation	-19592.95	-0.11	Alumina and aluminum production and processing	-1694.61	-0.08
10	Alumina and aluminum production and processing	-2250.96	-0.11	Non-metallic mineral product manufacturing (except cement and concrete products)	-2340.29	-0.08

### Top 10 increases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Residential building construction	184682.56	0.50	Non-residential building construction	75047.54	0.50
2	Architectural, engineering and related services	32186.68	0.33	Architectural, engineering and related services	34394.01	0.35
3	Other wood product manufacturing	3756.38	0.21	Household	245262.43	0.06
4	Sawmills and wood preservation	2316.25	0.20	Greenhouse, nursery and floriculture production	959.80	0.05
5	Veneer, plywood and engineered wood product manufacturing	1925.24	0.19	Electric lighting equipment manufacturing	182.37	0.04
6	Household and institutional furniture and kitchen cabinet manufacturing	3063.03	0.15	Specialized design services	589.75	0.04
7	Household	511571.42	0.13	Food, beverage and tobacco wholesaler-distributors	3056.25	0.03
8	Forestry and logging	1228.51	0.12	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	274.62	0.03
9	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	1141.19	0.10	Management, scientific and technical consulting services	1385.15	0.02
10	Support activities for forestry	205.49	0.07	Farm product wholesaler-distributors	166.27	0.02

## Ontario 'f2.5\_10' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.67	Cement and concrete product manufacturing	-89273.15	-2.41
2	Architectural and structural metals manufacturing	-70791.26	-1.43	Architectural and structural metals manufacturing	-45481.91	-0.92
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-5402.56	-1.05	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3519.36	-0.69
4	Other wood product manufacturing	-12878.04	-0.73	Stone mining and quarrying	-1707.47	-0.23
5	Sawmills and wood preservation	-7150.45	-0.63	Forging and stamping	-2290.78	-0.23
6	Veneer, plywood and engineered wood product manufacturing	-5861.76	-0.56	Non-metallic mineral product manufacturing (except cement and concrete products)	-6103.96	-0.21
7	Forging and stamping	-4973.55	-0.49	Electric lighting equipment manufacturing	-788.30	-0.19
8	Household and institutional furniture and kitchen cabinet manufacturing	-8703.82	-0.44	Boiler, tank and shipping container manufacturing	-2658.57	-0.17
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-11315.42	-0.39	Cutlery, hand tools and other fabricated metal product manufacturing	-3885.20	-0.14
10	Stone mining and quarrying	-2621.24	-0.35	Spring and wire product manufacturing	-501.71	-0.14

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	184682.56	0.50	Non-residential building construction	75047.54	0.50
2	Architectural, engineering and related services	31658.91	0.32	Architectural, engineering and related services	34287.65	0.35
3	Household	445121.26	0.12	Household	231142.91	0.06
4	Other electrical equipment and component manufacturing	798.75	0.04	Greenhouse, nursery and floriculture production	957.77	0.05
5	Greenhouse, nursery and floriculture production	769.38	0.04	Specialized design services	550.39	0.04
6	Professional and similar organizations	647.47	0.04	Food, beverage and tobacco wholesaler-distributors	2972.17	0.03
7	Private households	451.14	0.03	Farm product wholesaler-distributors	159.59	0.02
8	Owner-occupied dwellings	21631.01	0.03	Management, scientific and technical consulting services	1227.25	0.02
9	Funeral services	251.27	0.03	Private households	205.17	0.02
10	Gambling industries	722.74	0.03	Owner-occupied dwellings	9837.40	0.02

## Ontario 'f2.5\_45' Scenario

### Top 10 decreases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Other wood product manufacturing	-71098.51	-4.01	Cement and concrete product manufacturing	-89797.81	-2.42
2	Cement and concrete product manufacturing	-	-	Architectural and structural metals manufacturing	-53702.54	-1.08
		4				
3	Sawmills and wood preservation	-40283.92	-3.52	Electric lighting equipment manufacturing	-4185.65	-1.01
4	Veneer, plywood and engineered wood product manufacturing	-33116.27	-3.19	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3717.56	-0.72
5	Household and institutional furniture and kitchen cabinet manufacturing	-49887.79	-2.52	Non-metallic mineral product manufacturing (except cement and concrete products)	-19276.80	-0.67
6	Architectural and structural metals manufacturing	-	-	Spring and wire product manufacturing	-2038.91	-0.56
		1				
7	Forestry and logging	-20258.41	-1.95	Forging and stamping	-4267.15	-0.42
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-19100.63	-1.74	Boiler, tank and shipping container manufacturing	-6235.23	-0.40
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-42085.11	-1.46	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-4348.72	-0.40
10	Building material and garden equipment and supplies dealers	-55318.68	-1.37	Machine shops, turned product, and screw, nut and bolt manufacturing	-10963.95	-0.39

### Top 10 increases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Residential building construction	184682.56	0.50	Non-residential building construction	75047.54	0.50
2	Architectural, engineering and related services	29811.68	0.30	Architectural, engineering and related services	33915.36	0.35
3	Household	212545.13	0.06	Greenhouse, nursery and floriculture production	950.68	0.05
4	Greenhouse, nursery and floriculture production	718.94	0.04	Household	181724.57	0.05
5	Private households	445.84	0.03	Specialized design services	412.62	0.03
6	Owner-occupied dwellings	21376.57	0.03	Food, beverage and tobacco wholesaler-distributors	2677.87	0.02
7	Funeral services	245.95	0.03	Private households	204.00	0.02
8	Offices of dentists	1896.20	0.03	Owner-occupied dwellings	9781.13	0.02
9	Gambling industries	668.26	0.03	Funeral services	113.59	0.02
10	Urban transit systems	643.68	0.03	Gambling industries	320.16	0.01

## Ontario 'f2.5\_90' Scenario

### Top 10 decreases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Other wood product manufacturing	-	-8.23	Cement and concrete product manufacturing	-90472.36	-2.44
2	Sawmills and wood preservation	-82884.10	-7.25	Electric lighting equipment manufacturing	-8553.67	-2.06
3	Veneer, plywood and engineered wood product manufacturing	-68157.78	-6.56	Architectural and structural metals manufacturing	-64271.91	-1.30
4	Household and institutional furniture and kitchen cabinet manufacturing	-	-5.19	Non-metallic mineral product manufacturing (except cement and concrete products)	-36213.31	-1.25
5	Forestry and logging	-41745.33	-4.02	Spring and wire product manufacturing	-4015.31	-1.10
6	Cement and concrete product manufacturing	-	-3.76	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-8972.07	-0.82
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-39342.45	-3.59	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3972.40	-0.77
8	Architectural and structural metals manufacturing	-	-3.22	Machine shops, turned product, and screw, nut and bolt manufacturing	-20533.35	-0.73
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-81646.16	-2.83	Boiler, tank and shipping container manufacturing	-10833.79	-0.69
10	Building material and garden equipment and supplies dealers	-	-2.77	Forging and stamping	-6808.20	-0.67

### Top 10 increases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Residential building construction	184682.56	0.50	Non-residential building construction	75047.54	0.50
2	Architectural, engineering and related services	27436.67	0.28	Architectural, engineering and related services	33436.71	0.34
3	Private households	439.00	0.03	Greenhouse, nursery and floriculture production	941.55	0.05
4	Owner-occupied dwellings	21048.77	0.03	Household	118186.64	0.03
5	Greenhouse, nursery and floriculture production	654.07	0.03	Food, beverage and tobacco wholesaler-distributors	2299.48	0.02
6	Funeral services	239.11	0.03	Specialized design services	235.48	0.02
7	Offices of dentists	1856.35	0.03	Private households	202.49	0.02
8	Gambling industries	598.19	0.03	Owner-occupied dwellings	9708.76	0.02
9	Urban transit systems	579.02	0.03	Funeral services	112.11	0.02
10	BS Nursing and residential care facilities	833.26	0.02	Offices of dentists	862.09	0.01

## Ontario 'f5\_basic' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.55	Cement and concrete product manufacturing	-86652.10	-2.33
2	Architectural and structural metals manufacturing	-54994.51	-1.11	Architectural and structural metals manufacturing	-41243.81	-0.83
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-4959.80	-0.97	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3326.16	-0.65
4	Stone mining and quarrying	-2095.59	-0.28	Stone mining and quarrying	-1446.08	-0.19
5	Forging and stamping	-2395.35	-0.24	Forging and stamping	-1501.64	-0.15
6	Cutlery, hand tools and other fabricated metal product manufacturing	-4372.29	-0.16	Other activities of the construction industry	-1269.21	-0.10
7	Other activities of the construction industry	-1869.61	-0.14	Boiler, tank and shipping container manufacturing	-1274.00	-0.08
8	Boiler, tank and shipping container manufacturing	-1659.57	-0.11	Alumina and aluminum production and processing	-1511.71	-0.07
9	Iron and steel mills and ferro-alloy manufacturing	-8096.46	-0.09	Iron and steel mills and ferro-alloy manufacturing	-6042.71	-0.07
10	Alumina and aluminum production and processing	-1759.55	-0.08	Cutlery, hand tools and other fabricated metal product manufacturing	-1826.81	-0.07

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	369365.12	1.00	Non-residential building construction	150095.09	1.00
2	Other wood product manufacturing	7981.43	0.45	Architectural, engineering and related services	38635.78	0.39
3	Sawmills and wood preservation	4720.75	0.41	Electric lighting equipment manufacturing	448.50	0.11
4	Veneer, plywood and engineered wood product manufacturing	3892.36	0.37	Greenhouse, nursery and floriculture production	1924.98	0.10
5	Architectural, engineering and related services	36471.89	0.37	Household	305867.90	0.08
6	Household and institutional furniture and kitchen cabinet manufacturing	6167.73	0.31	Specialized design services	1052.39	0.07
7	Forestry and logging	2518.73	0.24	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	579.72	0.05
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	2350.75	0.21	Food, beverage and tobacco wholesaler-distributors	4211.23	0.04
9	Household	645131.09	0.17	Farm product wholesaler-distributors	328.79	0.03
10	Support activities for forestry	421.52	0.15	Furniture and home furnishings stores	981.10	0.03

## Ontario 'f5\_10' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.56	Cement and concrete product manufacturing	-86802.82	-2.34
2	Architectural and structural metals manufacturing	-66154.55	-1.33	Architectural and structural metals manufacturing	-43604.34	-0.88
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-5139.27	-1.00	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3383.09	-0.66
4	Other wood product manufacturing	-8735.92	-0.49	Forging and stamping	-2069.15	-0.20
5	Forging and stamping	-4343.17	-0.43	Stone mining and quarrying	-1509.73	-0.20
6	Sawmills and wood preservation	-4793.18	-0.42	Non-metallic mineral product manufacturing (except cement and concrete products)	-5012.93	-0.17
7	Veneer, plywood and engineered wood product manufacturing	-3933.47	-0.38	Boiler, tank and shipping container manufacturing	-2301.04	-0.15
8	Non-metallic mineral product manufacturing (except cement and concrete products)	-8860.01	-0.31	Electric lighting equipment manufacturing	-527.03	-0.13
9	Stone mining and quarrying	-2266.02	-0.30	Cutlery, hand tools and other fabricated metal product manufacturing	-3304.66	-0.12
10	Household and institutional furniture and kitchen cabinet manufacturing	-5658.23	-0.29	Spring and wire product manufacturing	-381.27	-0.10

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	369365.12	1.00	Non-residential building construction	150095.09	1.00
2	Architectural, engineering and related services	35940.66	0.37	Architectural, engineering and related services	38528.71	0.39
3	Household	578211.00	0.15	Greenhouse, nursery and floriculture production	1922.76	0.10
4	Other electrical equipment and component manufacturing	1847.56	0.10	Household	291647.30	0.08
5	Greenhouse, nursery and floriculture production	1562.53	0.08	Specialized design services	1012.74	0.07
6	Professional and similar organizations	1401.80	0.08	Food, beverage and tobacco wholesaler-distributors	4125.52	0.04
7	Private households	902.28	0.07	Farm product wholesaler-distributors	322.03	0.03
8	Owner-occupied dwellings	43262.01	0.07	Private households	410.34	0.03
9	Funeral services	504.21	0.07	Owner-occupied dwellings	19674.80	0.03
10	Gambling industries	1465.46	0.07	Funeral services	230.09	0.03

## Ontario 'f5\_45' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-67246.67	-3.79	Cement and concrete product manufacturing	-87330.35	-2.35
2	Cement and concrete product manufacturing	-133784.18	-3.60	Architectural and structural metals manufacturing	-51866.23	-1.05
3	Sawmills and wood preservation	-38091.92	-3.33	Electric lighting equipment manufacturing	-3941.39	-0.95
4	Veneer, plywood and engineered wood product manufacturing	-31323.86	-3.02	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3582.33	-0.70
5	Household and institutional furniture and kitchen cabinet manufacturing	-47049.10	-2.38	Non-metallic mineral product manufacturing (except cement and concrete products)	-18251.70	-0.63
6	Architectural and structural metals manufacturing	-105214.71	-2.12	Spring and wire product manufacturing	-1926.15	-0.53
7	Forestry and logging	-19076.31	-1.84	Forging and stamping	-4055.45	-0.40
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-17992.45	-1.64	Boiler, tank and shipping container manufacturing	-5895.70	-0.38
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-39784.55	-1.38	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-4066.77	-0.37
10	Building material and garden equipment and supplies dealers	-51609.59	-1.27	Machine shops, turned product, and screw, nut and bolt manufacturing	-10324.43	-0.37

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	369365.12	1.00	Non-residential building construction	150095.09	1.00
2	Architectural, engineering and related services	34081.35	0.35	Architectural, engineering and related services	38153.93	0.39
3	Household	343989.56	0.09	Greenhouse, nursery and floriculture production	1914.98	0.10
4	Greenhouse, nursery and floriculture production	1508.89	0.08	Household	241875.13	0.06
5	Private households	891.67	0.07	Specialized design services	873.97	0.06
6	Owner-occupied dwellings	42753.13	0.07	Food, beverage and tobacco wholesaler-distributors	3825.53	0.03
7	Funeral services	495.91	0.07	Private households	408.00	0.03
8	Gambling industries	1402.13	0.06	Owner-occupied dwellings	19562.27	0.03
9	Other electrical equipment and component manufacturing	1149.72	0.06	Farm product wholesaler-distributors	298.34	0.03
10	Offices of dentists	3804.27	0.06	Funeral services	228.28	0.03



## Ontario 'f5\_90' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-	-	Cement and concrete product manufacturing	-	-
		142474.7	-8.04		-88008.59	-2.37
2	Sawmills and wood preservation	-80904.59	-7.07	Electric lighting equipment manufacturing	-8331.28	-2.01
3	Veneer, plywood and engineered wood product manufacturing	-66540.08	-6.41	Architectural and structural metals manufacturing	-62488.65	-1.26
4	Household and institutional furniture and kitchen cabinet manufacturing	-	-	Non-metallic mineral product manufacturing (except cement and concrete products)	-35272.97	-1.22
		100265.9	-5.06			
5	Forestry and logging	-40671.36	-3.91	Spring and wire product manufacturing	-3912.43	-1.07
6	Cement and concrete product manufacturing	-	-	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-8713.27	-0.79
		135682.2	-3.66			
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-38335.65	-3.50	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3838.50	-0.75
8	Architectural and structural metals manufacturing	-	-	Machine shops, turned product, and screw, nut and bolt manufacturing	-19941.91	-0.71
		155434.9	-3.13			
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-79544.68	-2.76	Boiler, tank and shipping container manufacturing	-10517.40	-0.67
10	Building material and garden equipment and supplies dealers	-	-	Forging and stamping	-6609.27	-0.65
		108896.8	-2.69			

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	369365.1	1.00	Non-residential building construction	150095.09	1.00
		2				
2	Architectural, engineering and related services	31690.79	0.32	Architectural, engineering and related services	37672.07	0.38
3	Greenhouse, nursery and floriculture production	1439.90	0.07	Greenhouse, nursery and floriculture production	1904.97	0.10
4	Private households	878.00	0.07	Specialized design services	695.54	0.05
5	Owner-occupied dwellings	42097.54	0.07	Household	177882.22	0.05
6	Funeral services	485.23	0.07	Private households	404.98	0.03
7	Offices of dentists	3735.15	0.06	Owner-occupied dwellings	19417.52	0.03
8	Gambling industries	1320.65	0.06	Food, beverage and tobacco wholesaler-distributors	3439.82	0.03
9	Urban transit systems	1278.80	0.06	Funeral services	225.96	0.03
10	Personal care services and other personal services	2169.06	0.06	Gambling industries	637.64	0.03

## Ontario 'f10\_basic' Scenario

### Top 10 decreases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Cement and concrete product manufacturing	-	-3.35	Cement and concrete product manufacturing	-81709.79	-2.20
2	Architectural and structural metals manufacturing	-45609.66	-0.92	Architectural and structural metals manufacturing	-37465.09	-0.76
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-4431.31	-0.86	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3053.02	-0.59
4	Stone mining and quarrying	-1383.28	-0.18	Stone mining and quarrying	-1049.92	-0.14
5	Forging and stamping	-1115.05	-0.11	Forging and stamping	-1052.70	-0.10
6	Other activities of the construction industry	-1196.80	-0.09	Other activities of the construction industry	-894.76	-0.07
7	Cutlery, hand tools and other fabricated metal product manufacturing	-1517.94	-0.05	Alumina and aluminum production and processing	-1145.92	-0.05
8	Iron and steel mills and ferro-alloy manufacturing	-4704.66	-0.05	Iron and steel mills and ferro-alloy manufacturing	-4584.97	-0.05
9	Alumina and aluminum production and processing	-776.74	-0.04	Boiler, tank and shipping container manufacturing	-548.66	-0.03
10	Boiler, tank and shipping container manufacturing	-404.58	-0.03	Coating, engraving, heat treating and allied activities	-405.58	-0.03

### Top 10 increases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indus try Outp ut (%)		Total Industry Output (x1000)	Total Indus try Output (%)
1	Residential building construction	738730.24	2.00	Non-residential building construction	300190.18	2.00
2	Other wood product manufacturing	16431.54	0.93	Architectural, engineering and related services	47119.33	0.48
3	Sawmills and wood preservation	9529.73	0.83	Electric lighting equipment manufacturing	980.75	0.24
4	Veneer, plywood and engineered wood product manufacturing	7826.60	0.75	Greenhouse, nursery and floriculture production	3855.35	0.20
5	Household and institutional furniture and kitchen cabinet manufacturing	12377.12	0.62	Specialized design services	1977.67	0.13
6	Forestry and logging	5099.17	0.49	Household	427078.84	0.11
7	Architectural, engineering and related services	45042.29	0.46	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	1189.93	0.11
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	4769.87	0.44	Spring and wire product manufacturing	305.38	0.08
9	Building material and garden equipment and supplies dealers	13684.40	0.34	Furniture and home furnishings stores	2009.64	0.07
10	Support activities for forestry	853.59	0.31	Building material and garden equipment and supplies dealers	2873.39	0.07

## Ontario 'f10\_10' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.36	Cement and concrete product manufacturing	-81862.15	-2.21
2	Architectural and structural metals manufacturing	-56881.14	-1.15	Architectural and structural metals manufacturing	-39849.21	-0.80
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-4612.70	-0.90	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3110.54	-0.61
4	Forging and stamping	-3082.40	-0.31	Forging and stamping	-1625.89	-0.16
5	Stone mining and quarrying	-1555.59	-0.21	Stone mining and quarrying	-1114.23	-0.15
6	Cutlery, hand tools and other fabricated metal product manufacturing	-4950.17	-0.18	Boiler, tank and shipping container manufacturing	-1585.99	-0.10
7	Boiler, tank and shipping container manufacturing	-2181.06	-0.14	Non-metallic mineral product manufacturing (except cement and concrete products)	-2830.88	-0.10
8	Non-metallic mineral product manufacturing (except cement and concrete products)	-3949.20	-0.14	Cutlery, hand tools and other fabricated metal product manufacturing	-2143.59	-0.08
9	Other activities of the construction industry	-1392.40	-0.10	Other activities of the construction industry	-946.63	-0.07
10	Machine shops, turned product, and screw, nut and bolt manufacturing	-2743.85	-0.10	Alumina and aluminum production and processing	-1425.52	-0.07

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	738730.24	2.00	Non-residential building construction	300190.18	2.00
2	Architectural, engineering and related services	44504.16	0.45	Architectural, engineering and related services	47010.82	0.48
3	Household	844390.48	0.22	Greenhouse, nursery and floriculture production	3852.73	0.20
4	Other electrical equipment and component manufacturing	3945.20	0.22	Specialized design services	1937.45	0.13
5	Greenhouse, nursery and floriculture production	3148.83	0.16	Household	412656.06	0.11
6	Professional and similar organizations	2910.46	0.16	Farm product wholesaler-distributors	646.90	0.07
7	Private households	1804.57	0.14	Local credit unions	721.09	0.07
8	Owner-occupied dwellings	86524.02	0.14	Miscellaneous store retailers	1389.78	0.06
9	Specialized design services	2060.58	0.14	Private households	820.69	0.06
10	Petroleum and coal product manufacturing (except petroleum refineries)	4699.27	0.14	Owner-occupied dwellings	39349.60	0.06

## Ontario 'f10\_45' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-	-3.40	Cement and concrete product manufacturing	-82395.42	-2.22
2	Other wood product manufacturing	-59542.97	-3.36	Architectural and structural metals manufacturing	-48193.62	-0.97
3	Sawmills and wood preservation	-33707.92	-2.95	Electric lighting equipment manufacturing	-3452.87	-0.83
4	Veneer, plywood and engineered wood product manufacturing	-27739.04	-2.67	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3311.86	-0.65
5	Household and institutional furniture and kitchen cabinet manufacturing	-41371.72	-2.09	Non-metallic mineral product manufacturing (except cement and concrete products)	-16201.50	-0.56
6	Architectural and structural metals manufacturing	-96331.31	-1.94	Spring and wire product manufacturing	-1700.65	-0.46
7	Forestry and logging	-16712.11	-1.61	Forging and stamping	-3632.06	-0.36
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-15776.08	-1.44	Boiler, tank and shipping container manufacturing	-5216.63	-0.33
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-35183.43	-1.22	Machine shops, turned product, and screw, nut and bolt manufacturing	-9045.41	-0.32
10	Building material and garden equipment and supplies dealers	-44191.41	-1.09	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-3502.87	-0.32

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	738730.24	2.00	Non-residential building construction	300190.18	2.00
2	Architectural, engineering and related services	42620.68	0.44	Architectural, engineering and related services	46631.07	0.48
3	Other electrical equipment and component manufacturing	3238.89	0.18	Greenhouse, nursery and floriculture production	3843.58	0.20
4	Household	606878.43	0.16	Specialized design services	1796.67	0.12
5	Greenhouse, nursery and floriculture production	3088.78	0.16	Household	362176.24	0.10
6	Professional and similar organizations	2617.91	0.14	Farm product wholesaler-distributors	622.58	0.07
7	Private households	1783.34	0.14	Private households	815.99	0.06
8	Owner-occupied dwellings	85506.27	0.14	Owner-occupied dwellings	39124.54	0.06
9	Funeral services	995.83	0.14	Funeral services	457.67	0.06
10	Gambling industries	2869.86	0.13	Local credit unions	671.32	0.06

## Ontario 'f10\_90' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-135517.49	-7.65	Cement and concrete product manufacturing	-83081.05	-2.24
2	Sawmills and wood preservation	-76945.57	-6.73	Electric lighting equipment manufacturing	-7886.49	-1.90
3	Veneer, plywood and engineered wood product manufacturing	-63304.68	-6.10	Architectural and structural metals manufacturing	-58922.14	-1.19
4	Household and institutional furniture and kitchen cabinet manufacturing	-95120.59	-4.80	Non-metallic mineral product manufacturing (except cement and concrete products)	-33392.29	-1.16
5	Forestry and logging	-38523.41	-3.71	Spring and wire product manufacturing	-3706.69	-1.01
6	Cement and concrete product manufacturing	-128026.54	-3.45	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-8195.67	-0.75
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-36322.04	-3.31	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-3570.70	-0.70
8	Architectural and structural metals manufacturing	-147052.98	-2.97	Machine shops, turned product, and screw, nut and bolt manufacturing	-18759.03	-0.67
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-75341.73	-2.61	Boiler, tank and shipping container manufacturing	-9884.60	-0.63
10	Building material and garden equipment and supplies dealers	-102067.32	-2.52	Forging and stamping	-6211.41	-0.61

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	738730.24	2.00	Non-residential building construction	300190.18	2.00
2	Architectural, engineering and related services	40199.04	0.41	Architectural, engineering and related services	46142.80	0.47
3	Greenhouse, nursery and floriculture production	3011.56	0.16	Greenhouse, nursery and floriculture production	3831.80	0.20
4	Private households	1755.99	0.14	Specialized design services	1615.67	0.11
5	Owner-occupied dwellings	84195.07	0.14	Household	297273.38	0.08
6	Funeral services	977.46	0.13	Private households	809.95	0.06
7	Other electrical equipment and component manufacturing	2330.77	0.13	Owner-occupied dwellings	38835.04	0.06
8	Gambling industries	2765.57	0.13	Farm product wholesaler-distributors	591.31	0.06
9	Offices of dentists	7492.74	0.12	Funeral services	453.66	0.06
10	Professional and similar organizations	2241.74	0.12	Gambling industries	1302.36	0.06

## RoW 'Basic' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-10162.18	-3.76	Cement and concrete product manufacturing	-6668.31	-2.47
2	Architectural and structural metals manufacturing	-4686.98	-1.30	Architectural and structural metals manufacturing	-3277.76	-0.91
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-214.52	-1.07	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-140.69	-0.70
4	Stone mining and quarrying	-109.75	-0.38	Stone mining and quarrying	-72.01	-0.25
5	Forging and stamping	-267.60	-0.36	Forging and stamping	-142.01	-0.19
6	Cutlery, hand tools and other fabricated metal product manufacturing	-526.12	-0.26	Boiler, tank and shipping container manufacturing	-145.56	-0.13
7	Other activities of the construction industry	-109.90	-0.19	Other activities of the construction industry	-71.05	-0.12
8	Boiler, tank and shipping container manufacturing	-212.19	-0.19	Non-metallic mineral product manufacturing (except cement and concrete products)	-251.18	-0.12
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-365.74	-0.17	Cutlery, hand tools and other fabricated metal product manufacturing	-218.61	-0.11
10	Machine shops, turned product, and screw, nut and bolt manufacturing	-283.60	-0.14	Alumina and aluminum production and processing	-136.69	-0.09

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	1031.54	0.29	Architectural, engineering and related services	1114.76	0.31
2	Household	14063.66	0.10	Household	6870.03	0.05
3	Food, beverage and tobacco wholesaler-distributors	61.91	0.01	Food, beverage and tobacco wholesaler-distributors	73.18	0.02
4	Specialized design services	2.91	0.01	Specialized design services	4.70	0.01
5	Universities	26.28	0.00	Management, scientific and technical consulting services	15.25	0.01
6	Computer systems design and related services	17.70	0.00	Computer systems design and related services	37.41	0.00
7	Management, scientific and technical consulting services	1.54	0.00	Universities	29.64	0.00
8	Medical equipment and supplies manufacturing	0.55	0.00	Other professional, scientific and technical services	7.64	0.00
9	Other professional, scientific and technical services	0.43	0.00	Data processing, hosting, and related services	2.17	0.00
10	Private households	0.00	0.00	Medical equipment and supplies manufacturing	2.90	0.00

## RoW '10%' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-10192.53	-3.77	Cement and concrete product manufacturing	-6679.16	-2.47
2	Architectural and structural metals manufacturing	-5491.35	-1.52	Architectural and structural metals manufacturing	-3447.89	-0.96
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-221.46	-1.10	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-142.89	-0.71
4	Other wood product manufacturing	-1239.11	-0.96	Stone mining and quarrying	-74.47	-0.25
5	Sawmills and wood preservation	-692.19	-0.83	Electric lighting equipment manufacturing	-76.41	-0.25
6	Veneer, plywood and engineered wood product manufacturing	-567.14	-0.75	Non-metallic mineral product manufacturing (except cement and concrete products)	-523.81	-0.25
7	Household and institutional furniture and kitchen cabinet manufacturing	-855.39	-0.59	Forging and stamping	-182.91	-0.25
8	Forging and stamping	-407.98	-0.55	Boiler, tank and shipping container manufacturing	-219.58	-0.19
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-1002.55	-0.48	Spring and wire product manufacturing	-45.29	-0.17
10	Forestry and logging	-188.11	-0.46	Cutlery, hand tools and other fabricated metal product manufacturing	-325.12	-0.16

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	1012.16	0.28	Architectural, engineering and related services	1110.85	0.31
2	Household	11608.92	0.08	Household	6348.49	0.04
3	Food, beverage and tobacco wholesaler-distributors	47.87	0.01	Food, beverage and tobacco wholesaler-distributors	70.01	0.02
4	Universities	23.49	0.00	Specialized design services	3.25	0.01
5	Private households	0.00	0.00	Computer systems design and related services	30.82	0.00
6	Other educational services	0.00	0.00	Universities	29.04	0.00
7	Oil and gas engineering construction	0.00	0.00	Management, scientific and technical consulting services	9.46	0.00
8	Non-residential building construction	0.00	0.00	Other professional, scientific and technical services	4.43	0.00
9	Residential building construction	0.00	0.00	Professional and similar organizations	1.00	0.00
10	Electric power engineering construction	0.00	0.00	Medical equipment and supplies manufacturing	1.68	0.00

## RoW '45%' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-5456.58	-4.23	Cement and concrete product manufacturing	-6717.15	-2.49
2	Cement and concrete product manufacturing	-	-3.81	Architectural and structural metals manufacturing	-4043.37	-1.12
3	Sawmills and wood preservation	-3092.36	-3.71	Electric lighting equipment manufacturing	-322.51	-1.07
4	Veneer, plywood and engineered wood product manufacturing	-2541.44	-3.36	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-150.60	-0.75
5	Household and institutional furniture and kitchen cabinet manufacturing	-3838.62	-2.66	Non-metallic mineral product manufacturing (except cement and concrete products)	-1478.03	-0.70
6	Architectural and structural metals manufacturing	-8306.64	-2.30	Spring and wire product manufacturing	-156.65	-0.59
7	Forestry and logging	-838.06	-2.06	Forging and stamping	-326.07	-0.44
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-1471.25	-1.84	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-337.12	-0.42
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-3231.39	-1.54	Boiler, tank and shipping container manufacturing	-478.66	-0.42
10	Building material and garden equipment and supplies dealers	-2272.03	-1.46	Machine shops, turned product, and screw, nut and bolt manufacturing	-844.76	-0.41

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	944.31	0.26	Architectural, engineering and related services	1097.18	0.30
2	Household	3017.30	0.02	Household	4523.08	0.03
3	Universities	13.74	0.00	Food, beverage and tobacco wholesaler-distributors	58.90	0.01
4	Private households	0.00	0.00	Universities	26.97	0.00
5	Electric power engineering construction	0.00	0.00	Computer systems design and related services	7.78	0.00
6	Non-residential building construction	0.00	0.00	Private households	0.00	0.00
7	Transportation engineering construction	0.00	0.00	Communication engineering construction	0.00	0.00
8	Other educational services	0.00	0.00	Transportation engineering construction	0.00	0.00
9	Oil and gas engineering construction	0.00	0.00	Oil and gas engineering construction	0.00	0.00
10	Communication engineering construction	0.00	0.00	Electric power engineering construction	0.00	0.00



## RoW '90%' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-	-8.43	Cement and concrete product manufacturing	-6765.99	-2.50
2	Sawmills and wood preservation	-6178.29	-7.42	Electric lighting equipment manufacturing	-638.92	-2.11
3	Veneer, plywood and engineered wood product manufacturing	-5079.83	-6.72	Architectural and structural metals manufacturing	-4808.99	-1.33
4	Household and institutional furniture and kitchen cabinet manufacturing	-7674.21	-5.32	Non-metallic mineral product manufacturing (except cement and concrete products)	-2704.88	-1.29
5	Forestry and logging	-1673.70	-4.12	Spring and wire product manufacturing	-299.81	-1.12
6	Cement and concrete product manufacturing	-	-3.86	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-672.03	-0.84
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-2937.53	-3.68	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-160.50	-0.80
8	Architectural and structural metals manufacturing	-	-3.30	Machine shops, turned product, and screw, nut and bolt manufacturing	-1537.94	-0.75
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-6097.04	-2.90	Boiler, tank and shipping container manufacturing	-811.76	-0.71
10	Building material and garden equipment and supplies dealers	-4454.41	-2.86	Forging and stamping	-510.14	-0.69

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Architectural, engineering and related services	857.08	0.24	Architectural, engineering and related services	1079.60	0.30
2	Universities	1.20	0.00	Household	2176.12	0.02
3	Private households	0.00	0.00	Food, beverage and tobacco wholesaler-distributors	44.62	0.01
4	Other engineering construction	0.00	0.00	Universities	24.30	0.00
5	Other aboriginal government services	0.00	0.00	Private households	0.00	0.00
6	Communication engineering construction	0.00	0.00	Electric power engineering construction	0.00	0.00
7	Electric power engineering construction	0.00	0.00	Non-residential building construction	0.00	0.00
8	Oil and gas engineering construction	0.00	0.00	Transportation engineering construction	0.00	0.00
9	Non-residential building construction	0.00	0.00	Oil and gas engineering construction	0.00	0.00
10	Owner-occupied dwellings	0.00	0.00	Other educational services	0.00	0.00

## RoW 'f2.5\_basic' Scenario

### Top 10 decreases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indust ry Outpu t (%)		Total Industry Output (x1000)	Total Industr y Output (%)
1	Cement and concrete product manufacturing	-9881.91	-3.66	Cement and concrete product manufacturing	-6488.40	-2.40
2	Architectural and structural metals manufacturing	-4345.36	-1.20	Architectural and structural metals manufacturing	-3140.21	-0.87
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-204.19	-1.02	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-135.35	-0.67
4	Stone mining and quarrying	-95.83	-0.33	Stone mining and quarrying	-64.27	-0.22
5	Forging and stamping	-220.99	-0.30	Forging and stamping	-125.66	-0.17
6	Cutlery, hand tools and other fabricated metal product manufacturing	-422.22	-0.21	Other activities of the construction industry	-62.96	-0.11
7	Other activities of the construction industry	-95.36	-0.17	Boiler, tank and shipping container manufacturing	-119.15	-0.10
8	Boiler, tank and shipping container manufacturing	-166.50	-0.15	Cutlery, hand tools and other fabricated metal product manufacturing	-175.80	-0.09
9	Truck transportation	-839.70	-0.11	Alumina and aluminum production and processing	-123.37	-0.08
10	Alumina and aluminum production and processing	-163.88	-0.11	Non-metallic mineral product manufacturing (except cement and concrete products)	-170.38	-0.08

### Top 10 increases

R an k	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Indust ry Outpu t (%)		Total Industry Output (x1000)	Total Industr y Output (%)
1	Residential building construction	7983.28	0.50	Non-residential building construction	3244.08	0.50
2	Architectural, engineering and related services	1189.97	0.33	Architectural, engineering and related services	1271.58	0.35
3	Other wood product manufacturing	273.47	0.21	Household	9124.82	0.06
4	Sawmills and wood preservation	168.63	0.20	Greenhouse, nursery and floriculture production	29.33	0.05
5	Veneer, plywood and engineered wood product manufacturing	140.16	0.19	Electric lighting equipment manufacturing	13.28	0.04
6	Household and institutional furniture and kitchen cabinet manufacturing	223.00	0.15	Specialized design services	21.80	0.04
7	Household	19032.66	0.13	Food, beverage and tobacco wholesaler-distributors	117.64	0.03
8	Forestry and logging	48.02	0.12	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	19.99	0.03
9	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	83.08	0.10	Management, scientific and technical consulting services	51.21	0.02
10	Support activities for forestry	8.03	0.07	Farm product wholesaler-distributors	6.40	0.02

## RoW 'f2.5\_10' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-9912.44	-3.67	Cement and concrete product manufacturing	-6499.31	-2.41
2	Architectural and structural metals manufacturing	-5153.79	-1.43	Architectural and structural metals manufacturing	-3311.20	-0.92
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-211.17	-1.05	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-137.56	-0.69
4	Other wood product manufacturing	-937.55	-0.73	Stone mining and quarrying	-66.74	-0.23
5	Sawmills and wood preservation	-520.57	-0.63	Forging and stamping	-166.77	-0.23
6	Veneer, plywood and engineered wood product manufacturing	-426.75	-0.56	Non-metallic mineral product manufacturing (except cement and concrete products)	-444.38	-0.21
7	Forging and stamping	-362.09	-0.49	Electric lighting equipment manufacturing	-57.39	-0.19
8	Household and institutional furniture and kitchen cabinet manufacturing	-633.66	-0.44	Boiler, tank and shipping container manufacturing	-193.55	-0.17
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-823.79	-0.39	Cutlery, hand tools and other fabricated metal product manufacturing	-282.85	-0.14
10	Stone mining and quarrying	-102.46	-0.35	Spring and wire product manufacturing	-36.53	-0.14

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	7983.28	0.50	Non-residential building construction	3244.08	0.50
2	Architectural, engineering and related services	1170.46	0.32	Architectural, engineering and related services	1267.64	0.35
3	Household	16560.43	0.12	Household	8599.51	0.06
4	Other electrical equipment and component manufacturing	58.15	0.04	Greenhouse, nursery and floriculture production	29.27	0.05
5	Greenhouse, nursery and floriculture production	23.51	0.04	Specialized design services	20.35	0.04
6	Professional and similar organizations	20.09	0.04	Food, beverage and tobacco wholesaler-distributors	114.40	0.03
7	Private households	14.00	0.03	Farm product wholesaler-distributors	6.14	0.02
8	Owner-occupied dwellings	891.26	0.03	Management, scientific and technical consulting services	45.37	0.02
9	Funeral services	7.80	0.03	Private households	6.37	0.02
10	Gambling industries	23.29	0.03	Owner-occupied dwellings	405.33	0.02

## RoW 'f2.5\_45' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-5176.15	-4.01	Cement and concrete product manufacturing	-6537.51	-2.42
2	Cement and concrete product manufacturing	-	-3.71	Architectural and structural metals manufacturing	-3909.68	-1.08
3	Sawmills and wood preservation	-2932.77	-3.52	Electric lighting equipment manufacturing	-304.73	-1.01
4	Veneer, plywood and engineered wood product manufacturing	-2410.95	-3.19	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-145.31	-0.72
5	Household and institutional furniture and kitchen cabinet manufacturing	-3631.96	-2.52	Non-metallic mineral product manufacturing (except cement and concrete products)	-1403.40	-0.67
6	Architectural and structural metals manufacturing	-7983.27	-2.21	Spring and wire product manufacturing	-148.44	-0.56
7	Forestry and logging	-791.85	-1.95	Forging and stamping	-310.66	-0.42
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-1390.57	-1.74	Boiler, tank and shipping container manufacturing	-453.94	-0.40
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-3063.90	-1.46	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-316.60	-0.40
10	Building material and garden equipment and supplies dealers	-2129.27	-1.37	Machine shops, turned product, and screw, nut and bolt manufacturing	-798.20	-0.39

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	7983.28	0.50	Non-residential building construction	3244.08	0.50
2	Architectural, engineering and related services	1102.16	0.30	Architectural, engineering and related services	1253.88	0.35
3	Household	7907.59	0.06	Greenhouse, nursery and floriculture production	29.05	0.05
4	Greenhouse, nursery and floriculture production	21.97	0.04	Household	6760.94	0.05
5	Private households	13.84	0.03	Specialized design services	15.25	0.03
6	Owner-occupied dwellings	880.78	0.03	Food, beverage and tobacco wholesaler-distributors	103.07	0.02
7	Funeral services	7.63	0.03	Private households	6.33	0.02
8	Offices of dentists	62.00	0.03	Owner-occupied dwellings	403.01	0.02
9	Gambling industries	21.54	0.03	Funeral services	3.52	0.02
10	Urban transit systems	27.59	0.03	Gambling industries	10.32	0.01

## RoW 'f2.5\_90' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-	-8.23	Cement and concrete product manufacturing	-6586.62	-2.44
2	Sawmills and wood preservation	-6034.17	-7.25	Electric lighting equipment manufacturing	-622.73	-2.06
3	Veneer, plywood and engineered wood product manufacturing	-4962.06	-6.56	Architectural and structural metals manufacturing	-4679.16	-1.30
4	Household and institutional furniture and kitchen cabinet manufacturing	-7486.92	-5.19	Non-metallic mineral product manufacturing (except cement and concrete products)	-2636.42	-1.25
5	Forestry and logging	-1631.72	-4.02	Spring and wire product manufacturing	-292.32	-1.10
6	Cement and concrete product manufacturing	-	-3.76	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-653.19	-0.82
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-2864.23	-3.59	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-155.27	-0.77
8	Architectural and structural metals manufacturing	-	-3.22	Machine shops, turned product, and screw, nut and bolt manufacturing	-1494.88	-0.73
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-5944.05	-2.83	Boiler, tank and shipping container manufacturing	-788.73	-0.69
10	Building material and garden equipment and supplies dealers	-4322.98	-2.77	Forging and stamping	-495.65	-0.67

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	7983.28	0.50	Non-residential building construction	3244.08	0.50
2	Architectural, engineering and related services	1014.36	0.28	Architectural, engineering and related services	1236.18	0.34
3	Private households	13.62	0.03	Greenhouse, nursery and floriculture production	28.78	0.05
4	Owner-occupied dwellings	867.27	0.03	Household	4397.05	0.03
5	Greenhouse, nursery and floriculture production	19.99	0.03	Food, beverage and tobacco wholesaler-distributors	88.51	0.02
6	Funeral services	7.42	0.03	Specialized design services	8.71	0.02
7	Offices of dentists	60.70	0.03	Private households	6.28	0.02
8	Gambling industries	19.28	0.03	Owner-occupied dwellings	400.03	0.02
9	Urban transit systems	24.82	0.03	Funeral services	3.48	0.02
10	BS Nursing and residential care facilities	27.25	0.02	Offices of dentists	28.19	0.01

## RoW 'f5\_basic' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-9601.65	-3.55	Cement and concrete product manufacturing	-6308.49	-2.33
2	Architectural and structural metals manufacturing	-4003.74	-1.11	Architectural and structural metals manufacturing	-3002.65	-0.83
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-193.87	-0.97	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-130.01	-0.65
4	Stone mining and quarrying	-81.91	-0.28	Stone mining and quarrying	-56.52	-0.19
5	Forging and stamping	-174.39	-0.24	Forging and stamping	-109.32	-0.15
6	Cutlery, hand tools and other fabricated metal product manufacturing	-318.31	-0.16	Other activities of the construction industry	-54.86	-0.10
7	Other activities of the construction industry	-80.82	-0.14	Boiler, tank and shipping container manufacturing	-92.75	-0.08
8	Boiler, tank and shipping container manufacturing	-120.82	-0.11	Alumina and aluminum production and processing	-110.06	-0.07
9	Iron and steel mills and ferro-alloy manufacturing	-589.44	-0.09	Iron and steel mills and ferro-alloy manufacturing	-439.92	-0.07
10	Alumina and aluminum production and processing	-128.10	-0.08	Cutlery, hand tools and other fabricated metal product manufacturing	-133.00	-0.07

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	15966.56	1.00	Non-residential building construction	6488.17	1.00
2	Other wood product manufacturing	581.07	0.45	Architectural, engineering and related services	1428.40	0.39
3	Sawmills and wood preservation	343.68	0.41	Electric lighting equipment manufacturing	32.65	0.11
4	Veneer, plywood and engineered wood product manufacturing	283.37	0.37	Greenhouse, nursery and floriculture production	58.83	0.10
5	Architectural, engineering and related services	1348.40	0.37	Household	11379.60	0.08
6	Household and institutional furniture and kitchen cabinet manufacturing	449.03	0.31	Specialized design services	38.91	0.07
7	Forestry and logging	98.45	0.24	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	42.21	0.05
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	171.14	0.21	Food, beverage and tobacco wholesaler-distributors	162.09	0.04
9	Household	24001.65	0.17	Farm product wholesaler-distributors	12.66	0.03
10	Support activities for forestry	16.48	0.15	Furniture and home furnishings stores	37.76	0.03

## RoW 'f5\_10' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-9632.36	-3.56	Cement and concrete product manufacturing	-6319.47	-2.34
2	Architectural and structural metals manufacturing	-4816.22	-1.33	Architectural and structural metals manufacturing	-3174.51	-0.88
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-200.88	-1.00	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-132.24	-0.66
4	Other wood product manufacturing	-636.00	-0.49	Forging and stamping	-150.64	-0.20
5	Forging and stamping	-316.19	-0.43	Stone mining and quarrying	-59.01	-0.20
6	Sawmills and wood preservation	-348.96	-0.42	Non-metallic mineral product manufacturing (except cement and concrete products)	-364.95	-0.17
7	Veneer, plywood and engineered wood product manufacturing	-286.37	-0.38	Boiler, tank and shipping container manufacturing	-167.52	-0.15
8	Non-metallic mineral product manufacturing (except cement and concrete products)	-645.03	-0.31	Electric lighting equipment manufacturing	-38.37	-0.13
9	Stone mining and quarrying	-88.57	-0.30	Cutlery, hand tools and other fabricated metal product manufacturing	-240.59	-0.12
10	Household and institutional furniture and kitchen cabinet manufacturing	-411.93	-0.29	Spring and wire product manufacturing	-27.76	-0.10

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	15966.56	1.00	Non-residential building construction	6488.17	1.00
2	Architectural, engineering and related services	1328.76	0.37	Architectural, engineering and related services	1424.44	0.39
3	Household	21511.94	0.15	Greenhouse, nursery and floriculture production	58.76	0.10
4	Other electrical equipment and component manufacturing	134.51	0.10	Household	10850.54	0.08
5	Greenhouse, nursery and floriculture production	47.75	0.08	Specialized design services	37.44	0.07
6	Professional and similar organizations	43.50	0.08	Food, beverage and tobacco wholesaler-distributors	158.80	0.04
7	Private households	28.00	0.07	Farm product wholesaler-distributors	12.40	0.03
8	Owner-occupied dwellings	1782.52	0.07	Private households	12.73	0.03
9	Funeral services	15.65	0.07	Owner-occupied dwellings	810.66	0.03
10	Gambling industries	47.23	0.07	Funeral services	7.14	0.03

## RoW 'f5\_45' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-4895.73	-3.79	Cement and concrete product manufacturing	-6357.87	-2.35
2	Cement and concrete product manufacturing	-9739.83	-3.60	Architectural and structural metals manufacturing	-3775.99	-1.05
3	Sawmills and wood preservation	-2773.19	-3.33	Electric lighting equipment manufacturing	-286.94	-0.95
4	Veneer, plywood and engineered wood product manufacturing	-2280.46	-3.02	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-140.02	-0.70
5	Household and institutional furniture and kitchen cabinet manufacturing	-3425.30	-2.38	Non-metallic mineral product manufacturing (except cement and concrete products)	-1328.77	-0.63
6	Architectural and structural metals manufacturing	-7659.90	-2.12	Spring and wire product manufacturing	-140.23	-0.53
7	Forestry and logging	-745.65	-1.84	Forging and stamping	-295.25	-0.40
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-1309.90	-1.64	Boiler, tank and shipping container manufacturing	-429.22	-0.38
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-2896.42	-1.38	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-296.07	-0.37
10	Building material and garden equipment and supplies dealers	-1986.50	-1.27	Machine shops, turned product, and screw, nut and bolt manufacturing	-751.65	-0.37

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	15966.56	1.00	Non-residential building construction	6488.17	1.00
2	Architectural, engineering and related services	1260.02	0.35	Architectural, engineering and related services	1410.58	0.39
3	Household	12797.89	0.09	Greenhouse, nursery and floriculture production	58.53	0.10
4	Greenhouse, nursery and floriculture production	46.12	0.08	Household	8998.80	0.06
5	Private households	27.67	0.07	Specialized design services	32.31	0.06
6	Owner-occupied dwellings	1761.55	0.07	Food, beverage and tobacco wholesaler-distributors	147.25	0.03
7	Funeral services	15.39	0.07	Private households	12.66	0.03
8	Gambling industries	45.19	0.06	Owner-occupied dwellings	806.02	0.03
9	Other electrical equipment and component manufacturing	83.70	0.06	Farm product wholesaler-distributors	11.48	0.03
10	Offices of dentists	124.39	0.06	Funeral services	7.08	0.03



## RoW 'f5\_90' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-	-8.04	Cement and concrete product manufacturing	-6407.25	-2.37
2	Sawmills and wood preservation	-5890.06	-7.07	Electric lighting equipment manufacturing	-606.54	-2.01
3	Veneer, plywood and engineered wood product manufacturing	-4844.29	-6.41	Architectural and structural metals manufacturing	-4549.33	-1.26
4	Household and institutional furniture and kitchen cabinet manufacturing	-7299.62	-5.06	Non-metallic mineral product manufacturing (except cement and concrete products)	-2567.96	-1.22
5	Forestry and logging	-1589.74	-3.91	Spring and wire product manufacturing	-284.84	-1.07
6	Cement and concrete product manufacturing	-9878.02	-3.66	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-634.35	-0.79
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-2790.93	-3.50	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-150.04	-0.75
8	Architectural and structural metals manufacturing	-	-3.13	Machine shops, turned product, and screw, nut and bolt manufacturing	-1451.82	-0.71
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-5791.06	-2.76	Boiler, tank and shipping container manufacturing	-765.69	-0.67
10	Building material and garden equipment and supplies dealers	-4191.54	-2.69	Forging and stamping	-481.17	-0.65

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	15966.56	1.00	Non-residential building construction	6488.17	1.00
2	Architectural, engineering and related services	1171.64	0.32	Architectural, engineering and related services	1392.77	0.38
3	Greenhouse, nursery and floriculture production	44.01	0.07	Greenhouse, nursery and floriculture production	58.22	0.10
4	Private households	27.25	0.07	Specialized design services	25.71	0.05
5	Owner-occupied dwellings	1734.54	0.07	Household	6617.98	0.05
6	Funeral services	15.06	0.07	Private households	12.57	0.03
7	Offices of dentists	122.13	0.06	Owner-occupied dwellings	800.06	0.03
8	Gambling industries	42.56	0.06	Food, beverage and tobacco wholesaler-distributors	132.40	0.03
9	Urban transit systems	54.81	0.06	Funeral services	7.01	0.03
10	Personal care services and other personal services	67.31	0.06	Gambling industries	20.55	0.03

## RoW 'f10\_basic' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-9041.12	-3.35	Cement and concrete product manufacturing	-5948.68	-2.20
2	Architectural and structural metals manufacturing	-3320.50	-0.92	Architectural and structural metals manufacturing	-2727.55	-0.76
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-173.21	-0.86	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-119.34	-0.59
4	Stone mining and quarrying	-54.07	-0.18	Stone mining and quarrying	-41.04	-0.14
5	Forging and stamping	-81.18	-0.11	Forging and stamping	-76.64	-0.10
6	Other activities of the construction industry	-51.73	-0.09	Other activities of the construction industry	-38.68	-0.07
7	Cutlery, hand tools and other fabricated metal product manufacturing	-110.51	-0.05	Alumina and aluminum production and processing	-83.43	-0.05
8	Iron and steel mills and ferro-alloy manufacturing	-342.51	-0.05	Iron and steel mills and ferro-alloy manufacturing	-333.80	-0.05
9	Alumina and aluminum production and processing	-56.55	-0.04	Boiler, tank and shipping container manufacturing	-39.94	-0.03
10	Boiler, tank and shipping container manufacturing	-29.45	-0.03	Coating, engraving, heat treating and allied activities	-29.53	-0.03

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	31933.13	2.00	Non-residential building construction	12976.34	2.00
2	Other wood product manufacturing	1196.26	0.93	Architectural, engineering and related services	1742.04	0.48
3	Sawmills and wood preservation	693.79	0.83	Electric lighting equipment manufacturing	71.40	0.24
4	Veneer, plywood and engineered wood product manufacturing	569.80	0.75	Greenhouse, nursery and floriculture production	117.83	0.20
5	Household and institutional furniture and kitchen cabinet manufacturing	901.09	0.62	Specialized design services	73.12	0.13
6	Forestry and logging	199.31	0.49	Household	15889.17	0.11
7	Architectural, engineering and related services	1665.25	0.46	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	86.63	0.11
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	347.26	0.44	Spring and wire product manufacturing	22.23	0.08
9	Building material and garden equipment and supplies dealers	526.73	0.34	Furniture and home furnishings stores	77.35	0.07
10	Support activities for forestry	33.36	0.31	Building material and garden equipment and supplies dealers	110.60	0.07

## RoW 'f10\_10' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-9072.18	-3.36	Cement and concrete product manufacturing	-5959.77	-2.21
2	Architectural and structural metals manufacturing	-4141.09	-1.15	Architectural and structural metals manufacturing	-2901.12	-0.80
3	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-180.30	-0.90	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-121.58	-0.61
4	Forging and stamping	-224.41	-0.31	Forging and stamping	-118.37	-0.16
5	Stone mining and quarrying	-60.80	-0.21	Stone mining and quarrying	-43.55	-0.15
6	Cutlery, hand tools and other fabricated metal product manufacturing	-360.39	-0.18	Boiler, tank and shipping container manufacturing	-115.46	-0.10
7	Boiler, tank and shipping container manufacturing	-158.79	-0.14	Non-metallic mineral product manufacturing (except cement and concrete products)	-206.10	-0.10
8	Non-metallic mineral product manufacturing (except cement and concrete products)	-287.51	-0.14	Cutlery, hand tools and other fabricated metal product manufacturing	-156.06	-0.08
9	Other activities of the construction industry	-60.19	-0.10	Other activities of the construction industry	-40.92	-0.07
10	Machine shops, turned product, and screw, nut and bolt manufacturing	-199.76	-0.10	Alumina and aluminum production and processing	-103.78	-0.07

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	31933.13	2.00	Non-residential building construction	12976.34	2.00
2	Architectural, engineering and related services	1645.36	0.45	Architectural, engineering and related services	1738.03	0.48
3	Household	31414.96	0.22	Greenhouse, nursery and floriculture production	117.75	0.20
4	Other electrical equipment and component manufacturing	287.22	0.22	Specialized design services	71.63	0.13
5	Greenhouse, nursery and floriculture production	96.24	0.16	Household	15352.58	0.11
6	Professional and similar organizations	90.32	0.16	Farm product wholesaler-distributors	24.90	0.07
7	Private households	56.00	0.14	Local credit unions	29.71	0.07
8	Owner-occupied dwellings	3565.04	0.14	Miscellaneous store retailers	53.49	0.06
9	Specialized design services	76.18	0.14	Private households	25.47	0.06
10	Petroleum and coal product manufacturing (except petroleum refineries)	342.12	0.14	Owner-occupied dwellings	1621.32	0.06

## RoW 'f10\_45' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Cement and concrete product manufacturing	-9180.89	-3.40	Cement and concrete product manufacturing	-5998.60	-2.22
2	Other wood product manufacturing	-4334.88	-3.36	Architectural and structural metals manufacturing	-3508.62	-0.97
3	Sawmills and wood preservation	-2454.02	-2.95	Electric lighting equipment manufacturing	-251.38	-0.83
4	Veneer, plywood and engineered wood product manufacturing	-2019.47	-2.67	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-129.45	-0.65
5	Household and institutional furniture and kitchen cabinet manufacturing	-3011.97	-2.09	Non-metallic mineral product manufacturing (except cement and concrete products)	-1179.51	-0.56
6	Architectural and structural metals manufacturing	-7013.17	-1.94	Spring and wire product manufacturing	-123.81	-0.46
7	Forestry and logging	-653.24	-1.61	Forging and stamping	-264.42	-0.36
8	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-1148.54	-1.44	Boiler, tank and shipping container manufacturing	-379.78	-0.33
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-2561.44	-1.22	Machine shops, turned product, and screw, nut and bolt manufacturing	-658.53	-0.32
10	Building material and garden equipment and supplies dealers	-1700.97	-1.09	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-255.02	-0.32

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	31933.13	2.00	Non-residential building construction	12976.34	2.00
2	Architectural, engineering and related services	1575.72	0.44	Architectural, engineering and related services	1723.99	0.48
3	Other electrical equipment and component manufacturing	235.80	0.18	Greenhouse, nursery and floriculture production	117.47	0.20
4	Household	22578.49	0.16	Specialized design services	66.42	0.12
5	Greenhouse, nursery and floriculture production	94.40	0.16	Household	13474.52	0.10
6	Professional and similar organizations	81.24	0.14	Farm product wholesaler-distributors	23.96	0.07
7	Private households	55.34	0.14	Private households	25.32	0.06
8	Owner-occupied dwellings	3523.11	0.14	Owner-occupied dwellings	1612.04	0.06
9	Funeral services	30.90	0.14	Funeral services	14.20	0.06
10	Gambling industries	92.49	0.13	Local credit unions	27.66	0.06

## RoW 'f10\_90' Scenario

### Top 10 decreases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Other wood product manufacturing	-9866.02	-7.65	Cement and concrete product manufacturing	-6048.51	-2.24
2	Sawmills and wood preservation	-5601.83	-6.73	Electric lighting equipment manufacturing	-574.16	-1.90
3	Veneer, plywood and engineered wood product manufacturing	-4608.74	-6.10	Architectural and structural metals manufacturing	-4289.68	-1.19
4	Household and institutional furniture and kitchen cabinet manufacturing	-6925.02	-4.80	Non-metallic mineral product manufacturing (except cement and concrete products)	-2431.04	-1.16
5	Forestry and logging	-1505.78	-3.71	Spring and wire product manufacturing	-269.86	-1.01
6	Cement and concrete product manufacturing	-9320.66	-3.45	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-596.67	-0.75
7	Ventilation, heating, air-conditioning and commercial refrigeration equipment manufacturing	-2644.34	-3.31	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	-139.57	-0.70
8	Architectural and structural metals manufacturing	-	-2.97	Machine shops, turned product, and screw, nut and bolt manufacturing	-1365.71	-0.67
9	Non-metallic mineral product manufacturing (except cement and concrete products)	-5485.07	-2.61	Boiler, tank and shipping container manufacturing	-719.62	-0.63
10	Building material and garden equipment and supplies dealers	-3928.67	-2.52	Forging and stamping	-452.21	-0.61

### Top 10 increases

Rank	Industry	Residential building construction		Industry	Non-residential building construction	
		Total Industry Output (x1000)	Total Industry Output (%)		Total Industry Output (x1000)	Total Industry Output (%)
1	Residential building construction	31933.13	2.00	Non-residential building construction	12976.34	2.00
2	Architectural, engineering and related services	1486.19	0.41	Architectural, engineering and related services	1705.94	0.47
3	Greenhouse, nursery and floriculture production	92.04	0.16	Greenhouse, nursery and floriculture production	117.11	0.20
4	Private households	54.49	0.14	Specialized design services	59.73	0.11
5	Owner-occupied dwellings	3469.08	0.14	Household	11059.85	0.08
6	Funeral services	30.33	0.13	Private households	25.13	0.06
7	Other electrical equipment and component manufacturing	169.69	0.13	Owner-occupied dwellings	1600.12	0.06
8	Gambling industries	89.13	0.13	Farm product wholesaler-distributors	22.76	0.06
9	Offices of dentists	245.00	0.12	Funeral services	14.08	0.06
10	Professional and similar organizations	69.57	0.12	Gambling industries	41.97	0.06